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2 of 2

ERDA-1538
UC-70

Final Environmental Statement

Waste Management Operations

Hanford Reservation

Richland, Washington

December 1975

United States
Energy Research & Development
Administration

Volume 2
(2 of 2 Volumes)

Appendixes

BEST AVAILABLE COPY

Responsible Official:

James L. Liverman

James L. Liverman
Assistant Administrator For
Environment & Safety

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SUMMARY OF CONTENTS

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APPENDIX II.1-A

DETAIL MAP OF THE HANFORD RESERVATION

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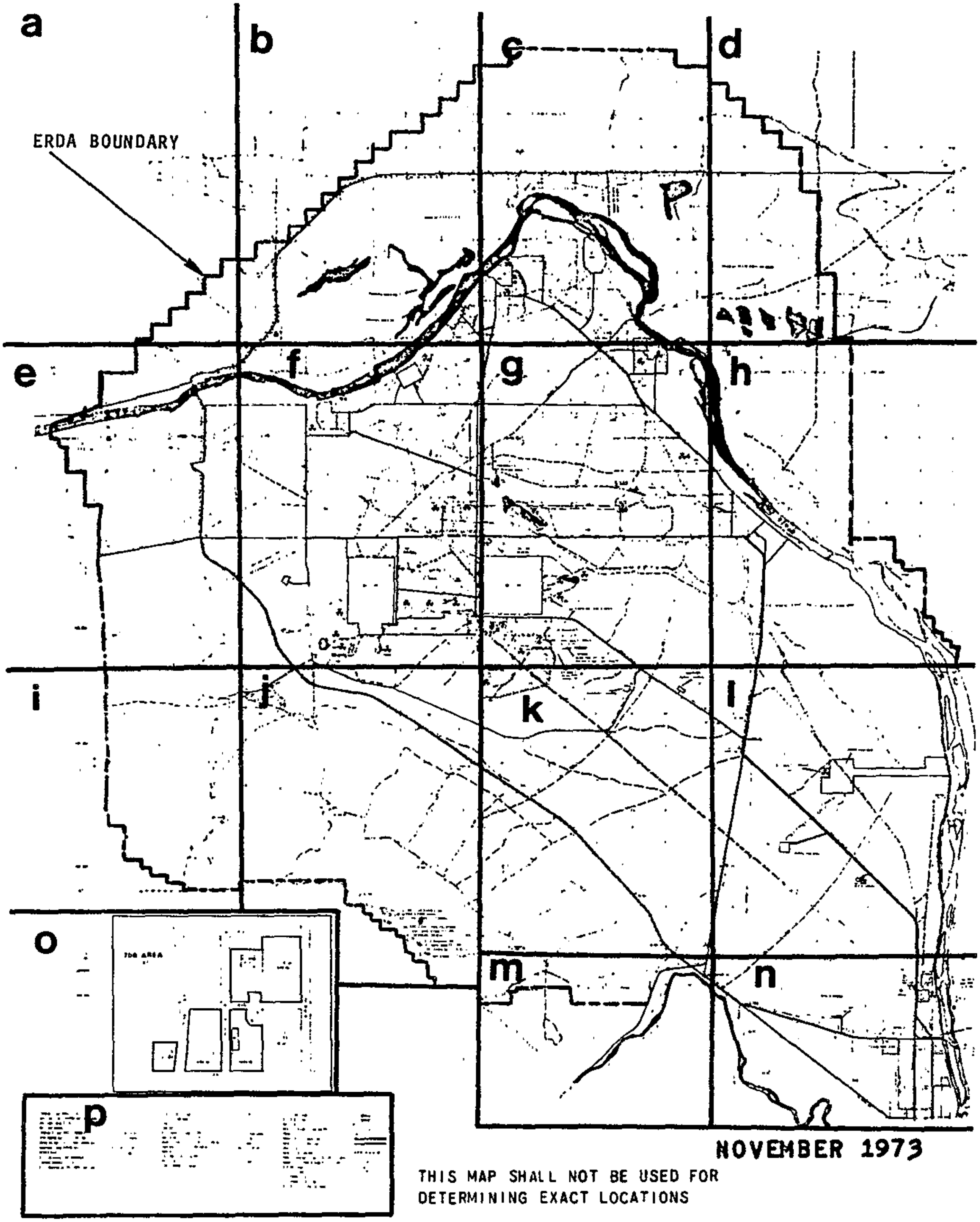

FIGURE II.1-A-1 ERDA HANFORD RESERVATION DETAIL MAP. Enlarged sections appear on the following pages.

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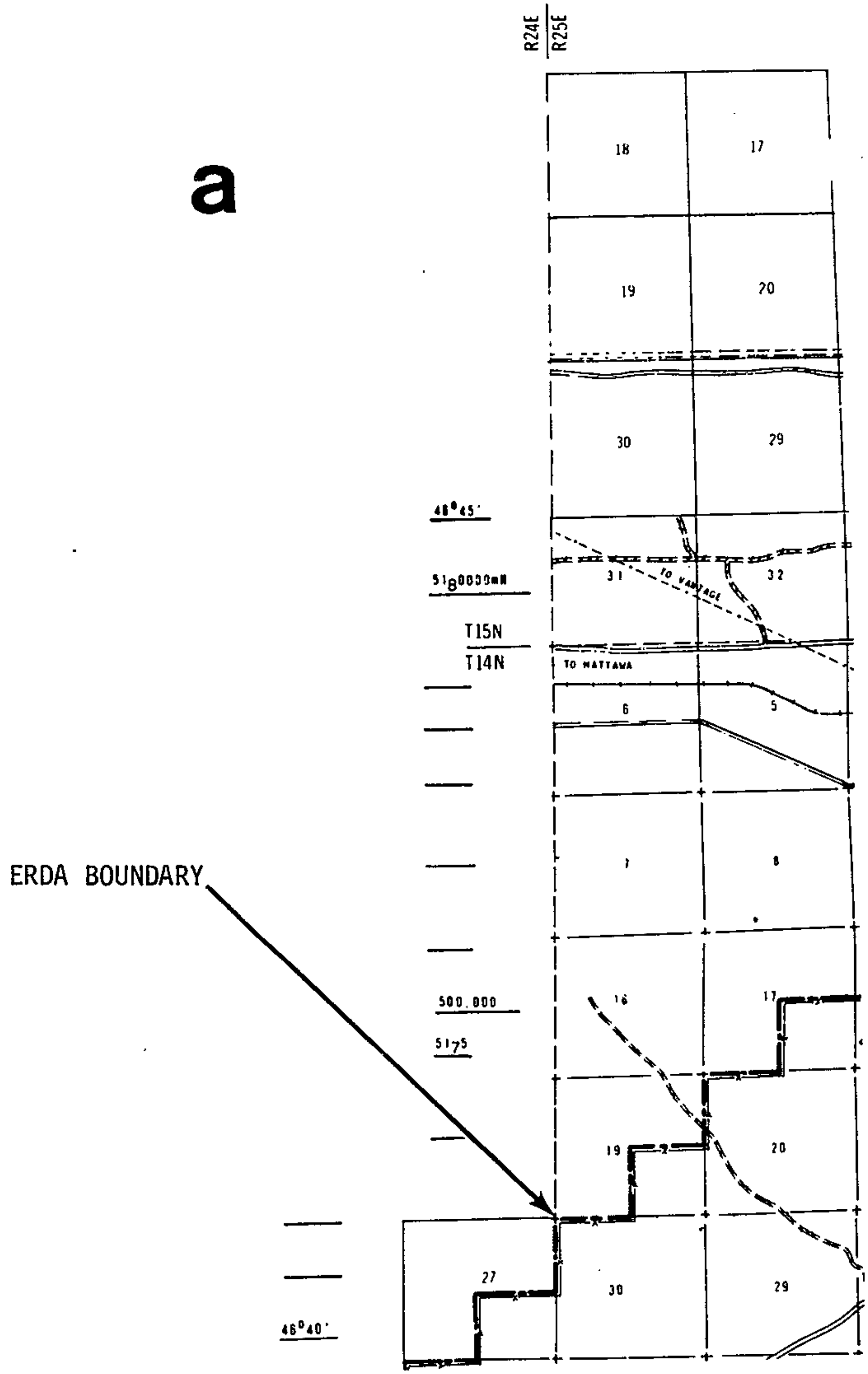

FIGURE II.1-A-1a

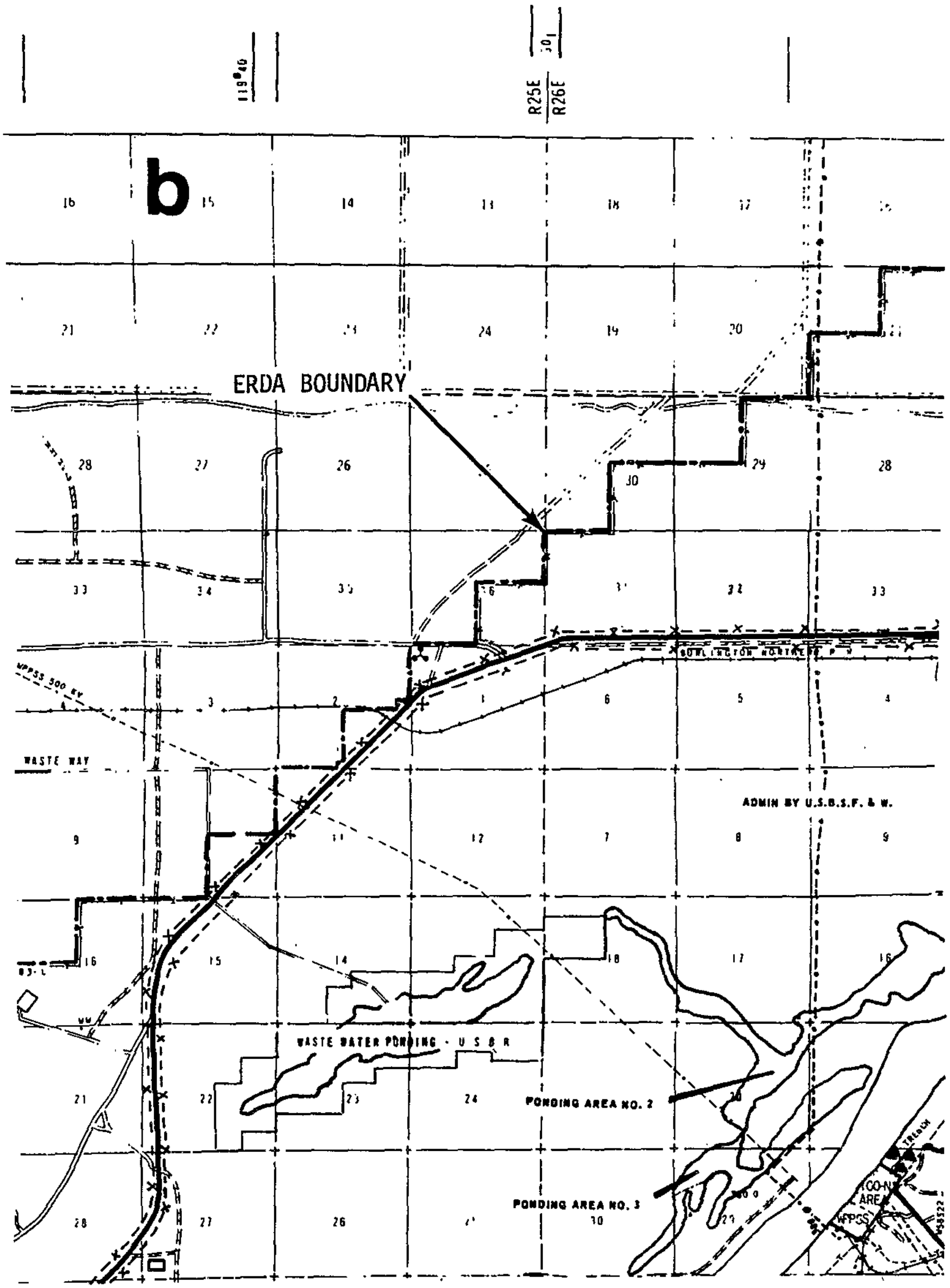

FIGURE II.1-A-1b

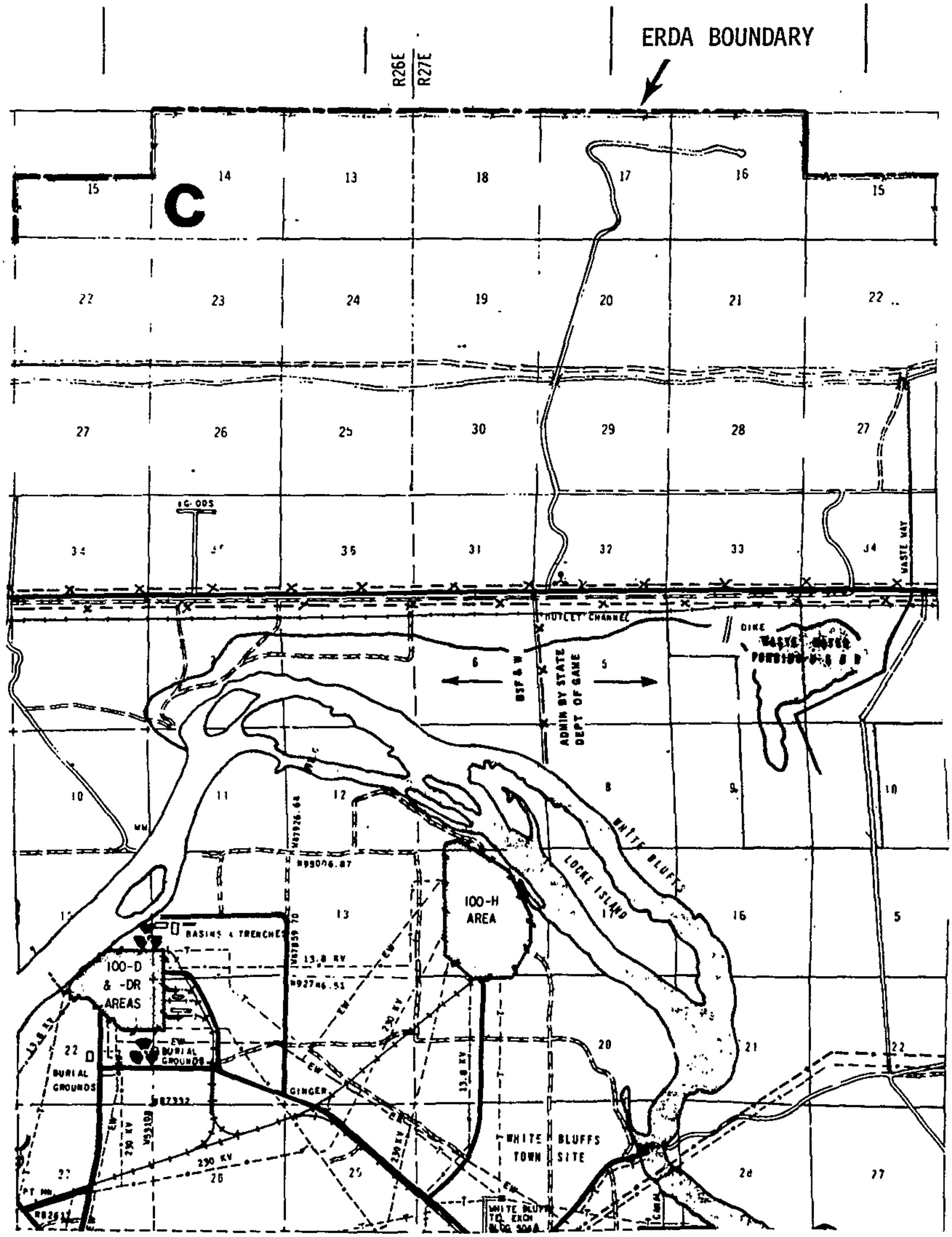

FIGURE II.1-A-1c

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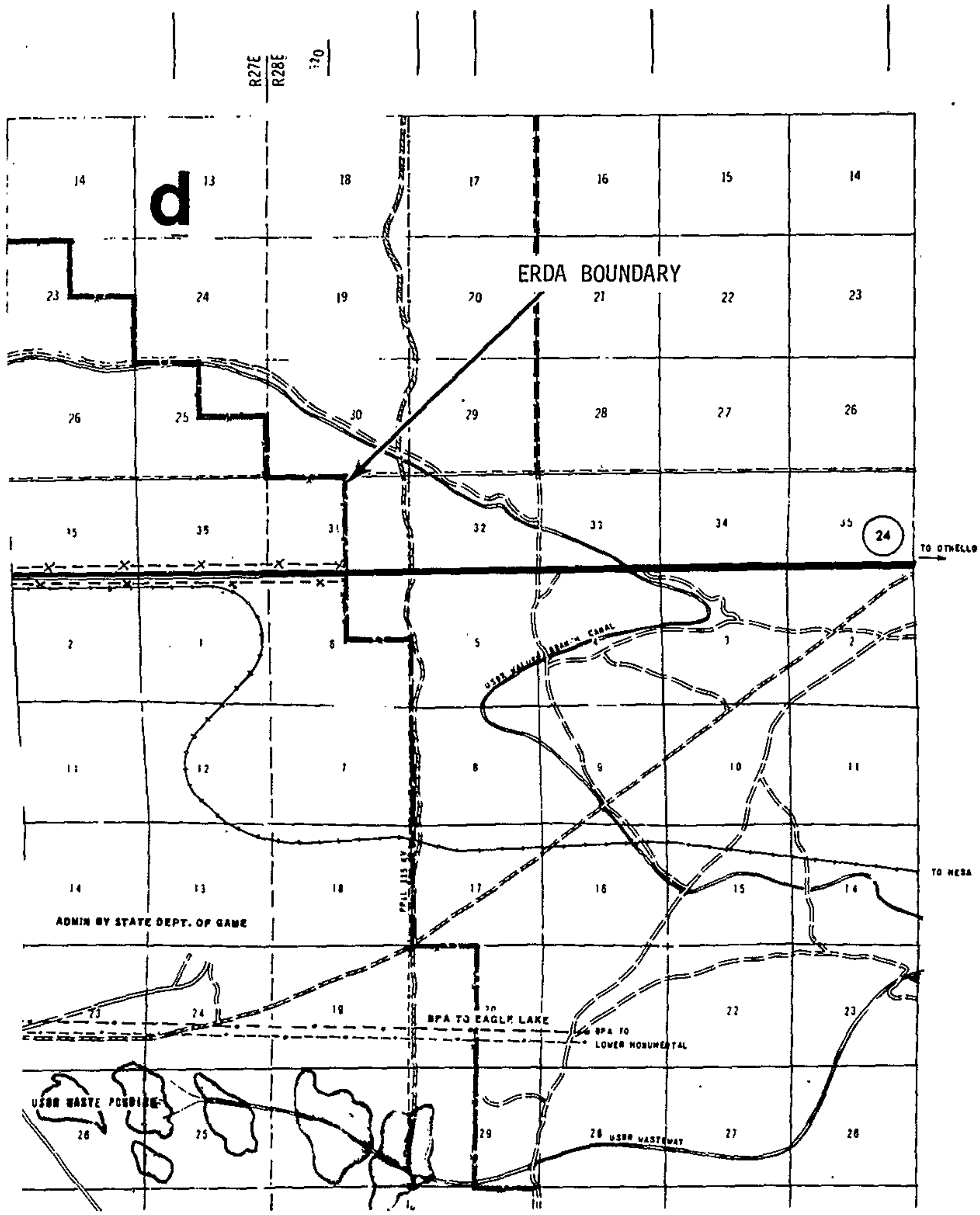

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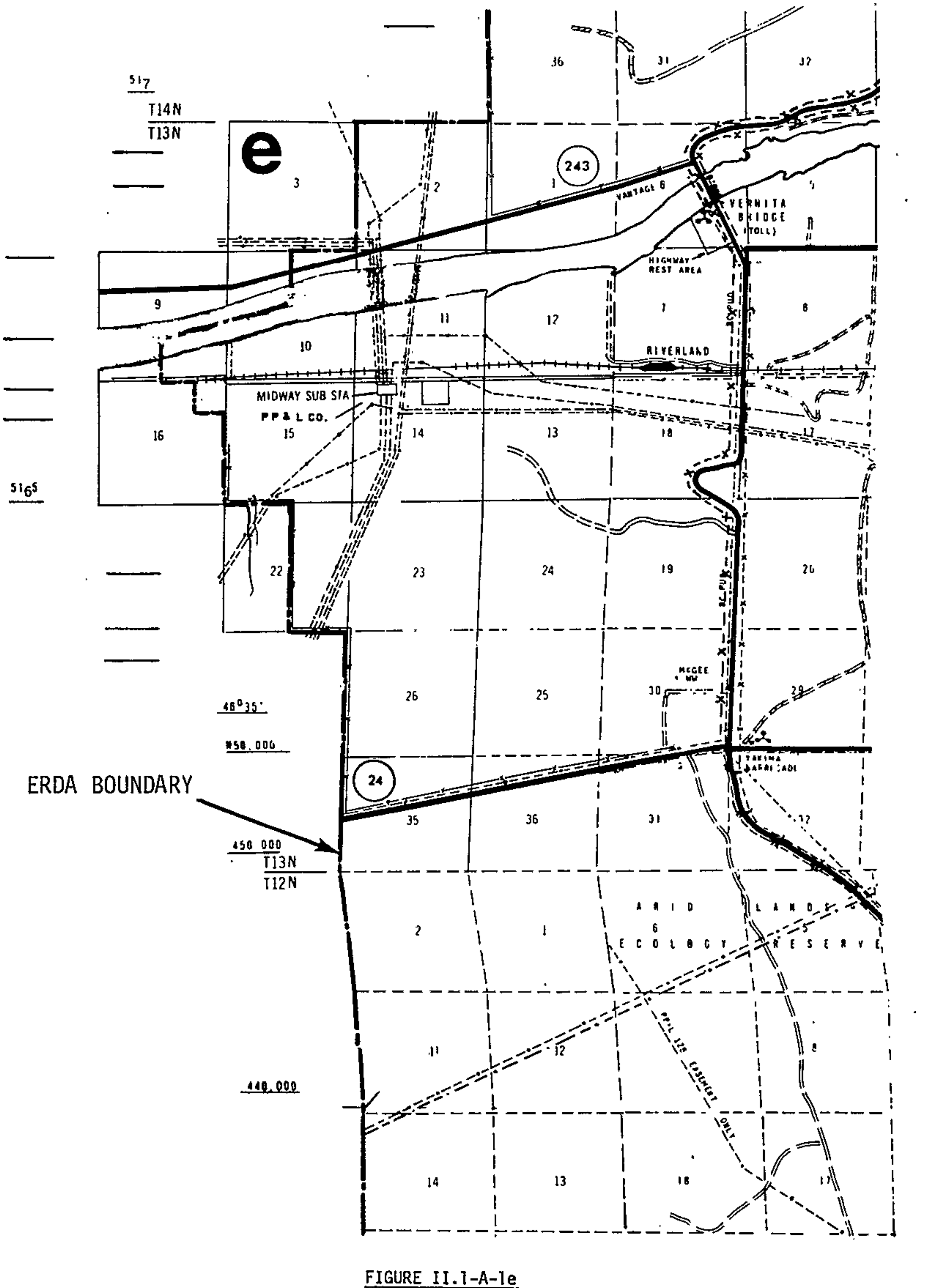

FIGURE II.1-A-1e

9 1 1 1 3 9 1 1 0 3 7

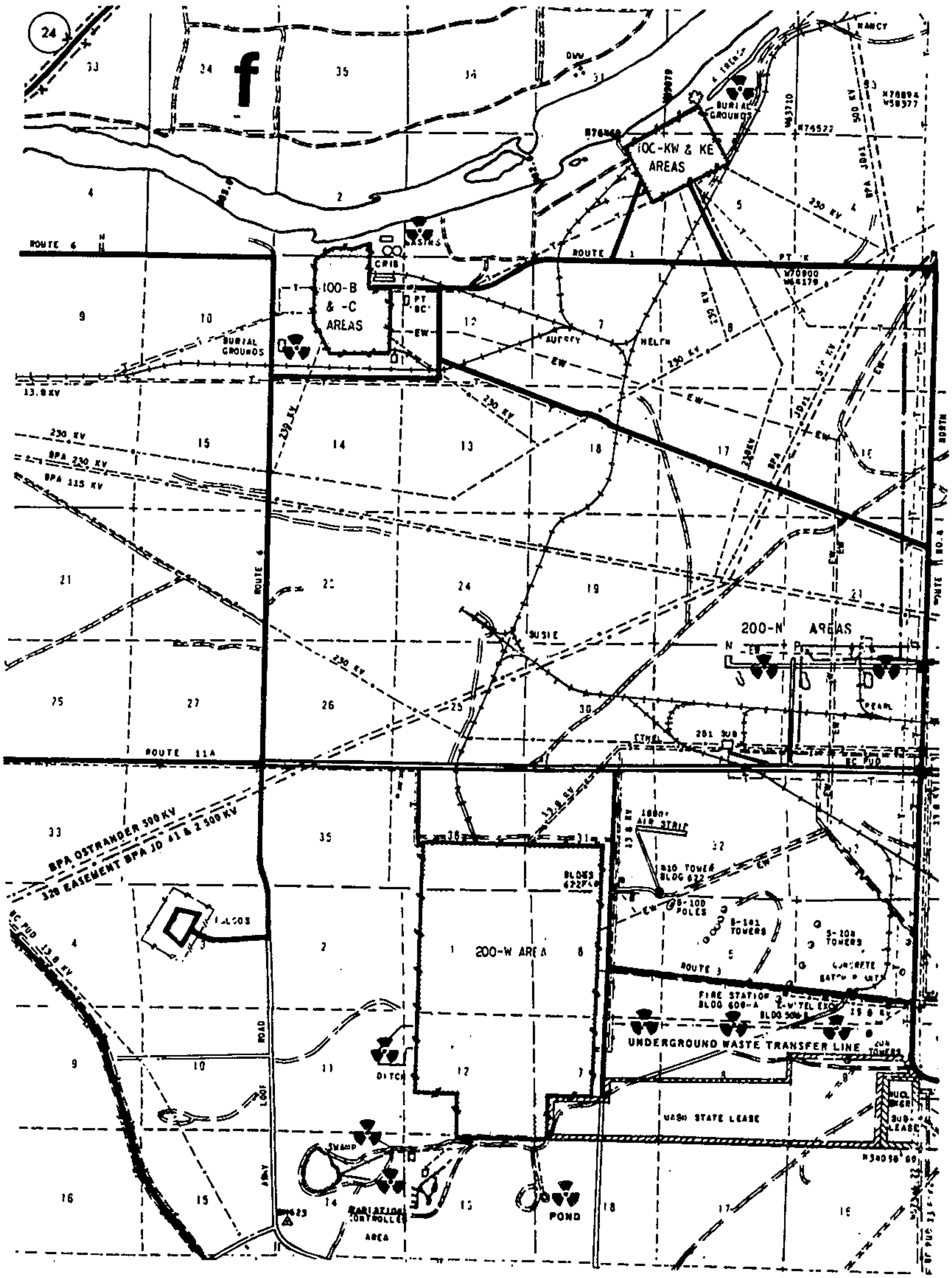

FIGURE II.1-A-1f

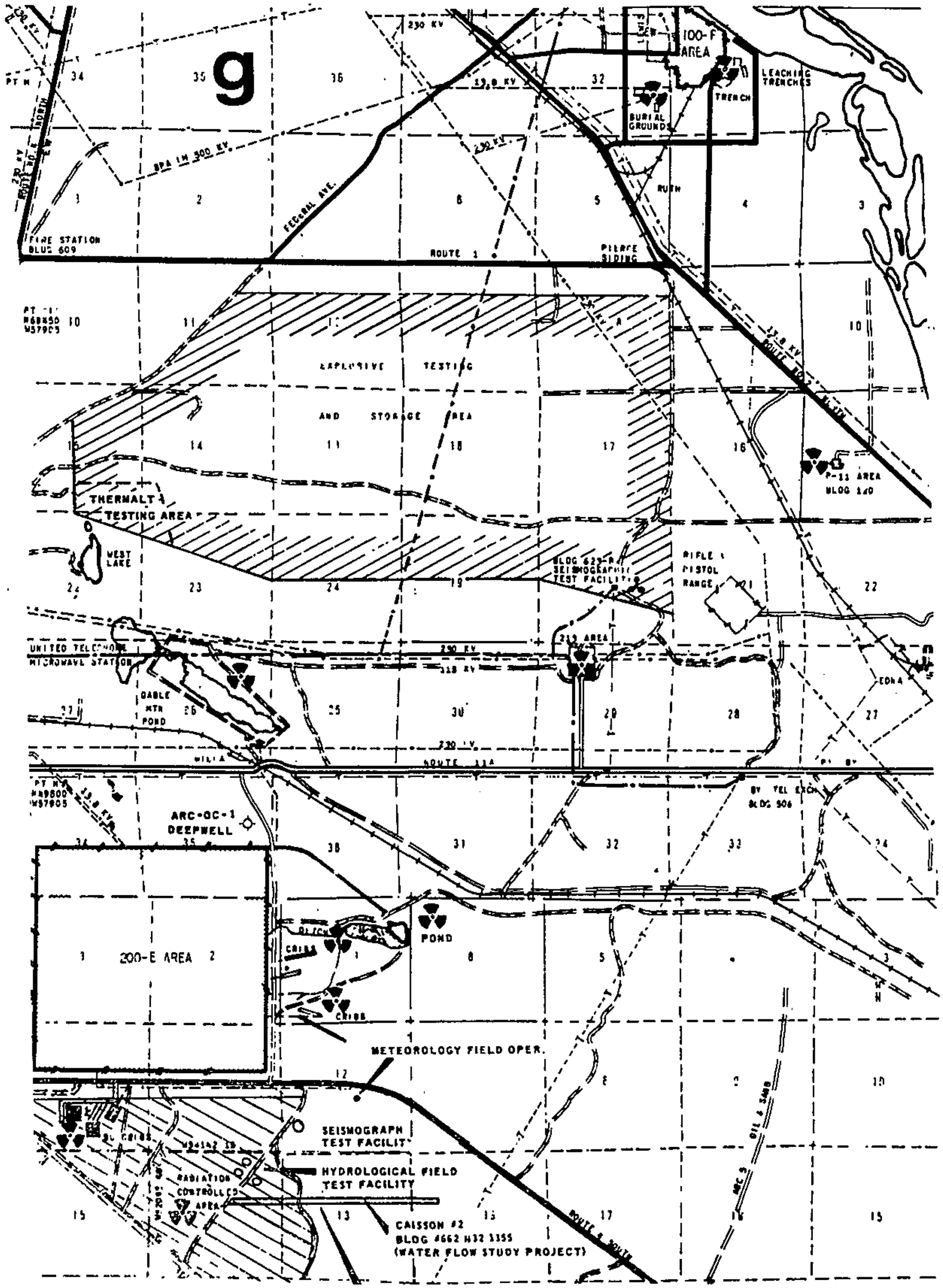

FIGURE II.1-A-1g

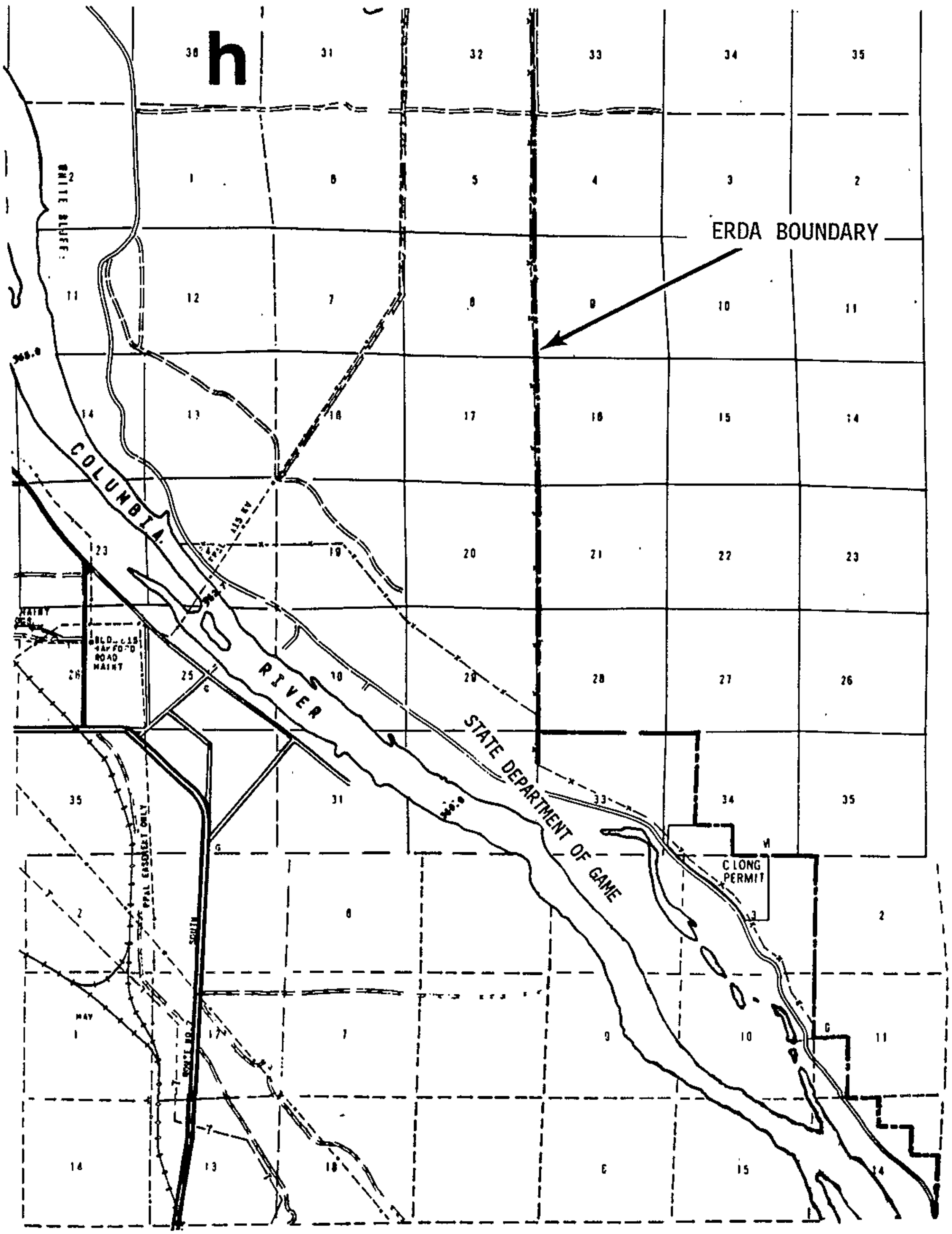

FIGURE II.1-A-1h

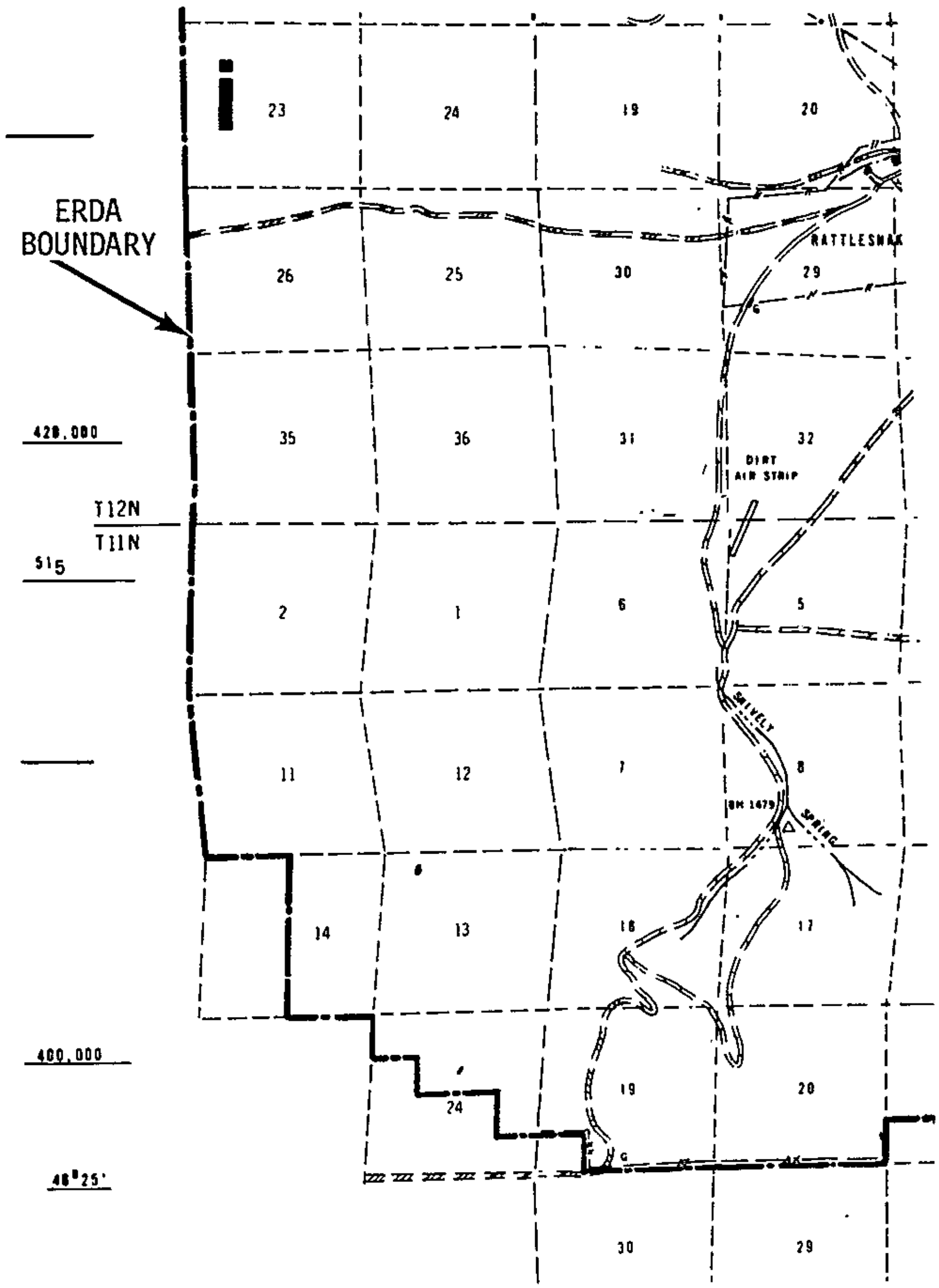

FIGURE II.1-A-1i

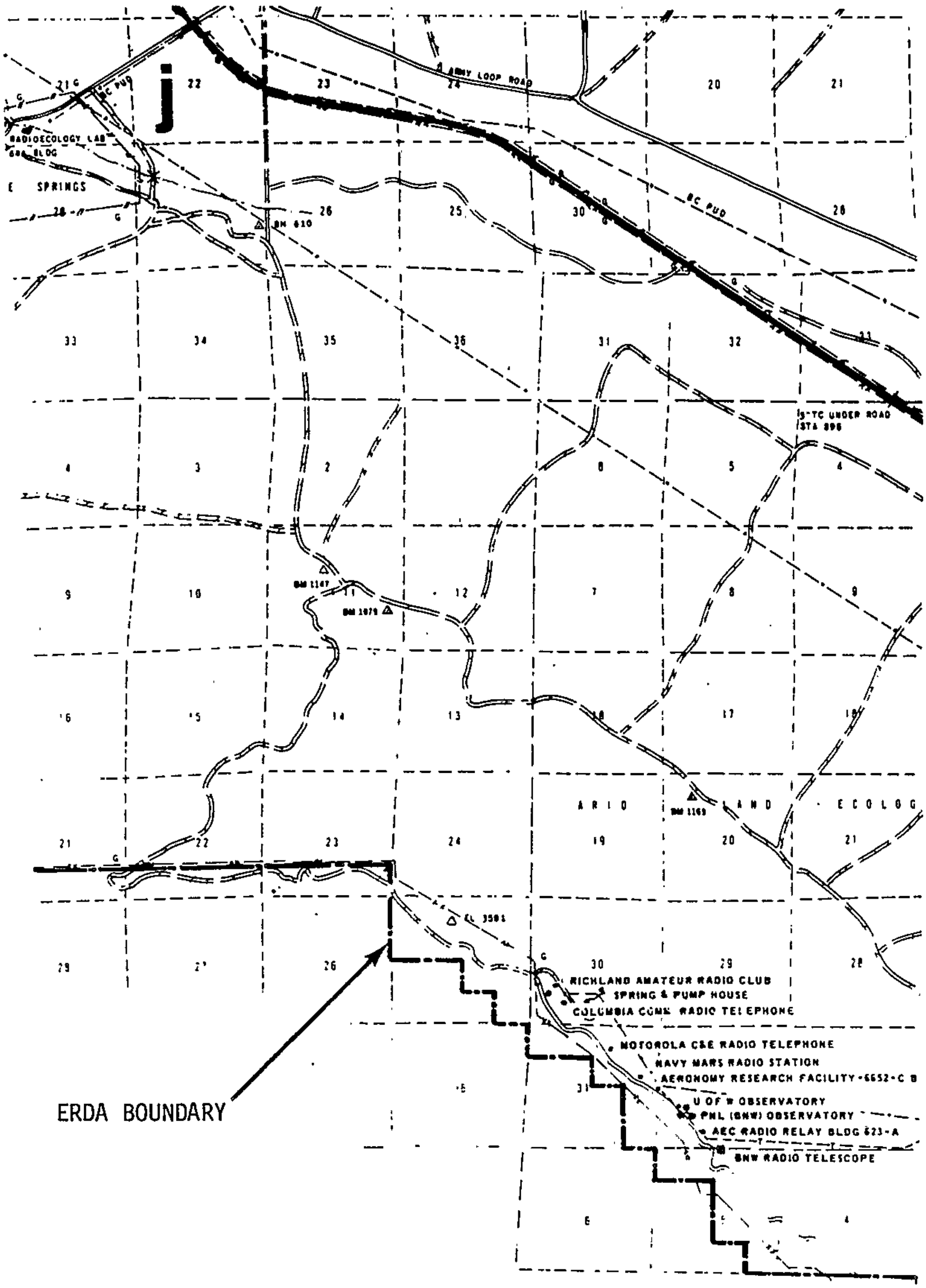

FIGURE II.1-A-1j

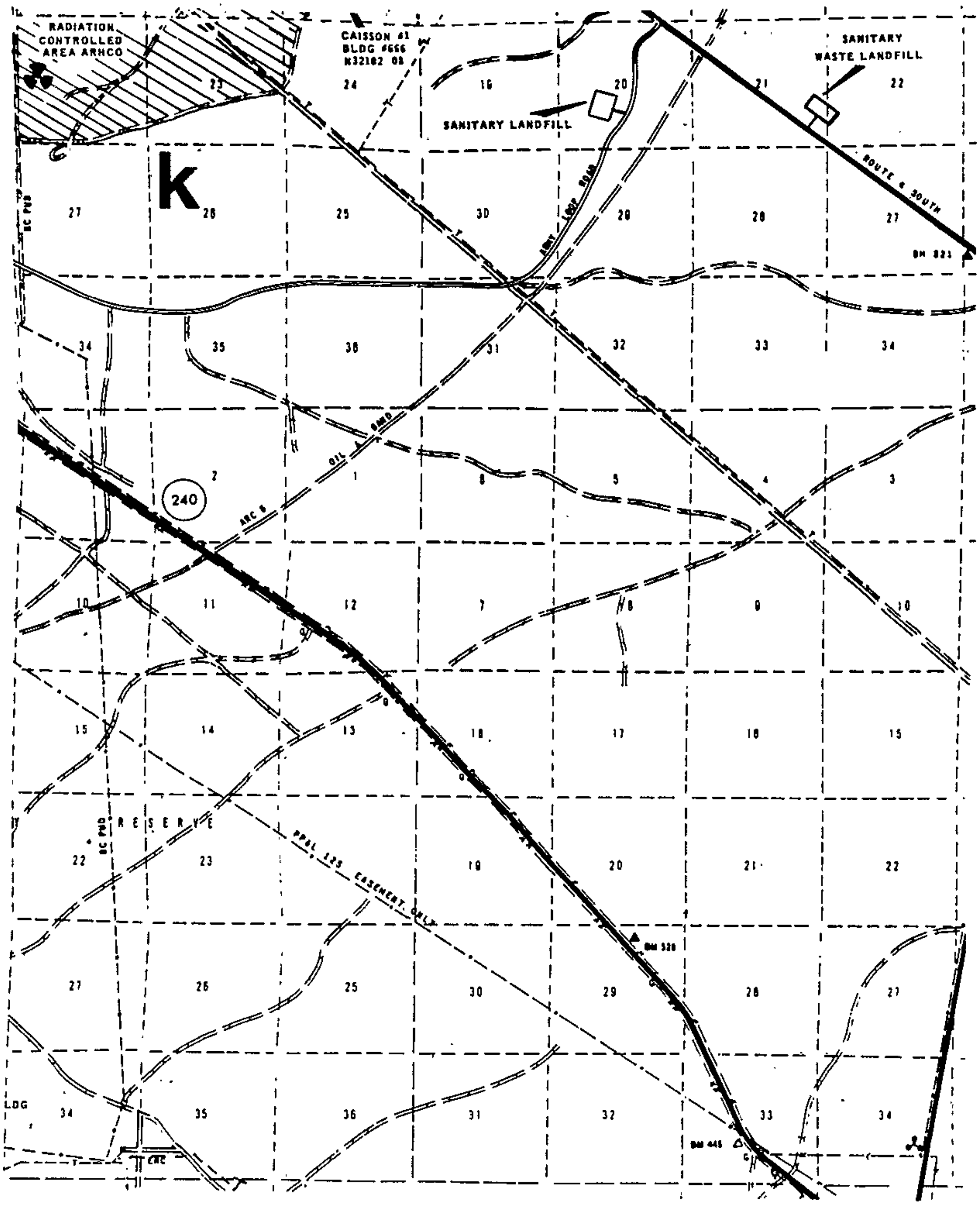

FIGURE II.1-A-1k

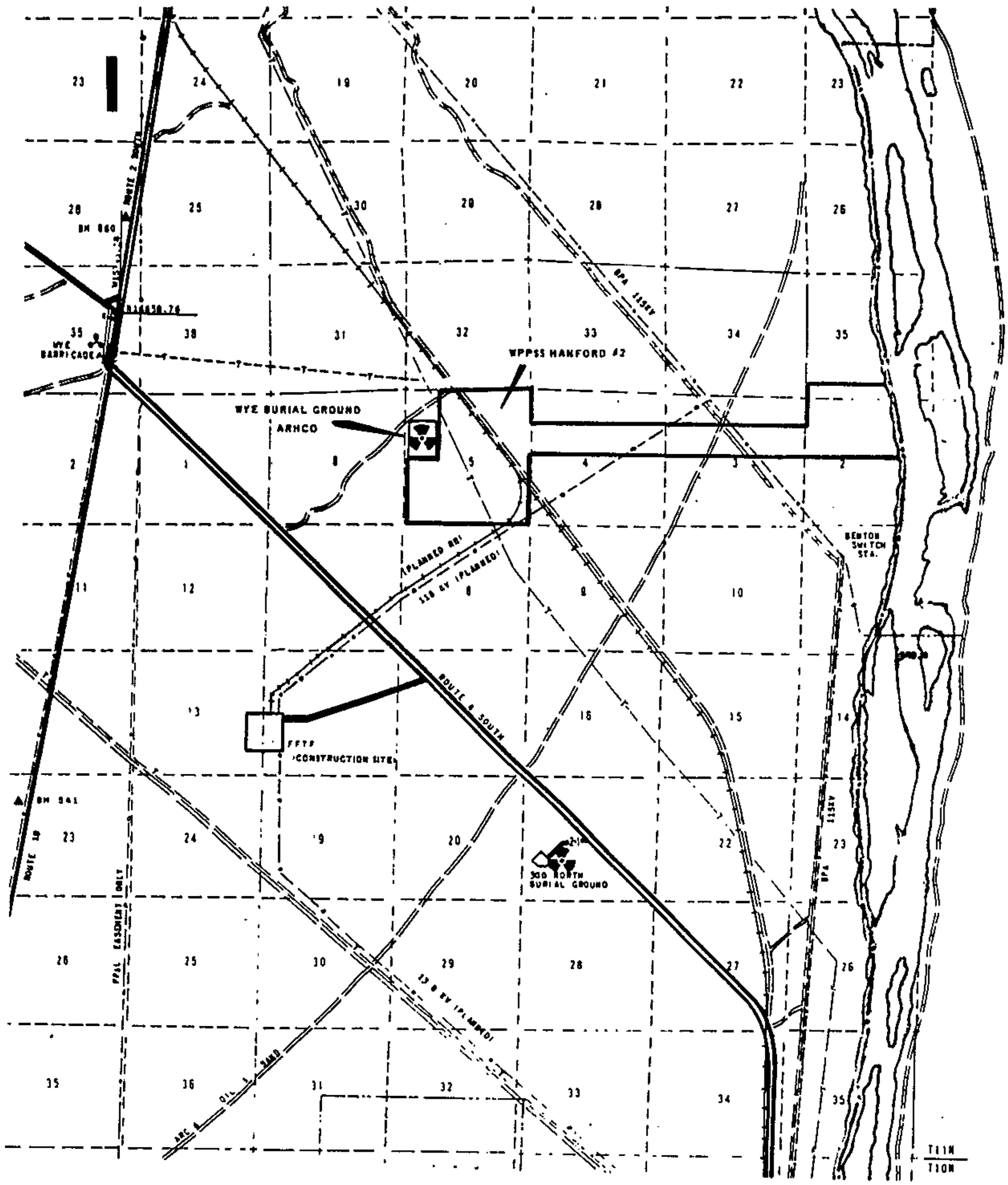

FIGURE II.1-A-11

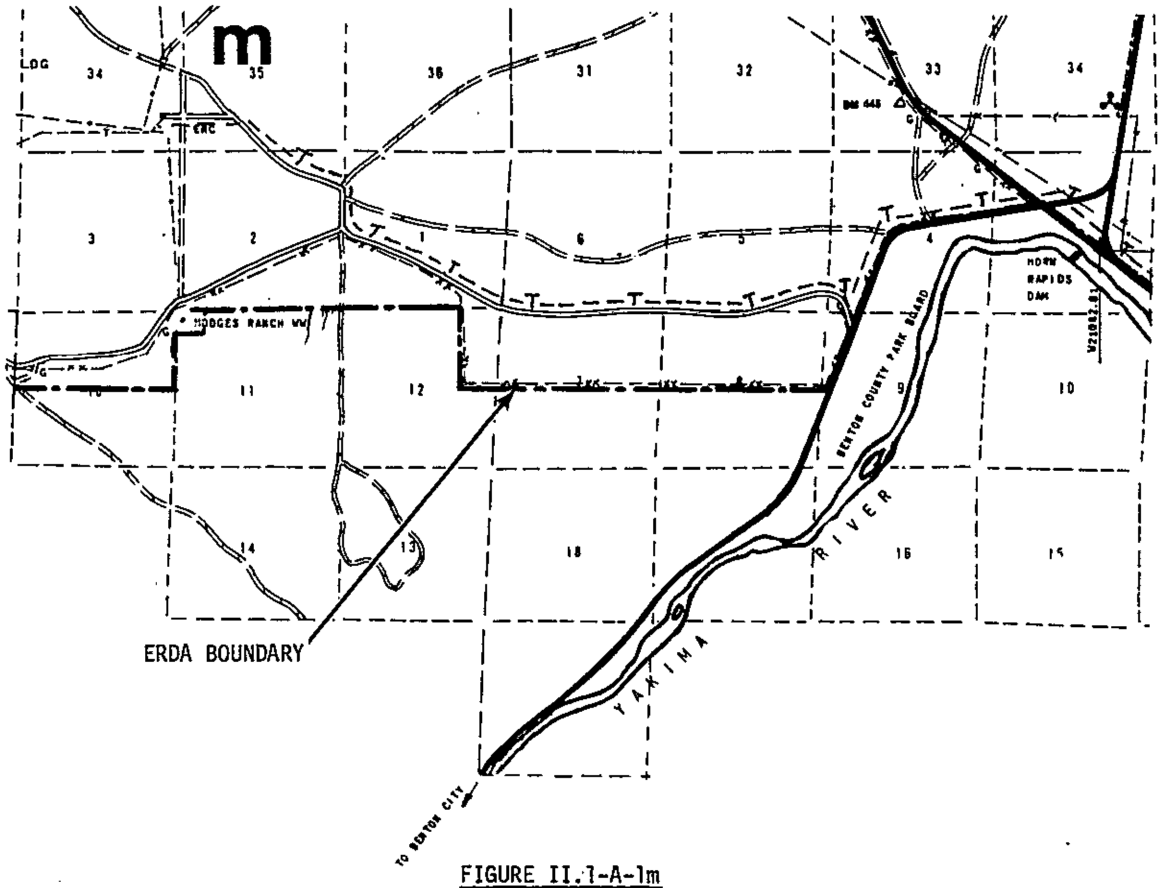

FIGURE II.1-A-1m

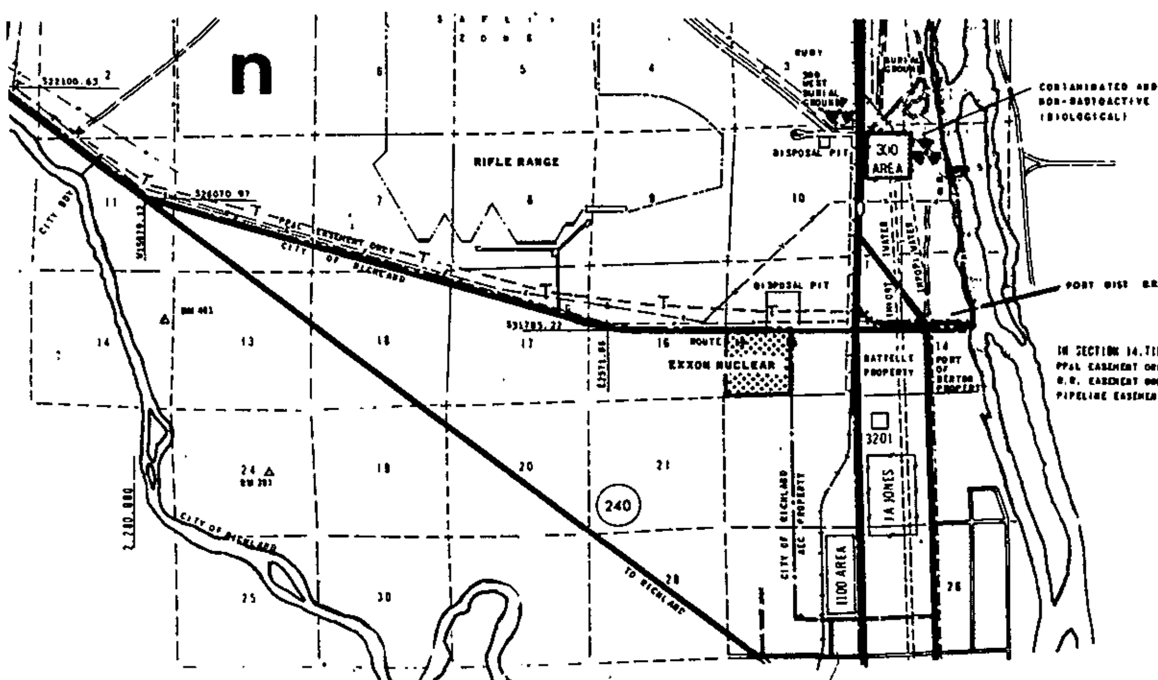

FIGURE II.1-A-1n

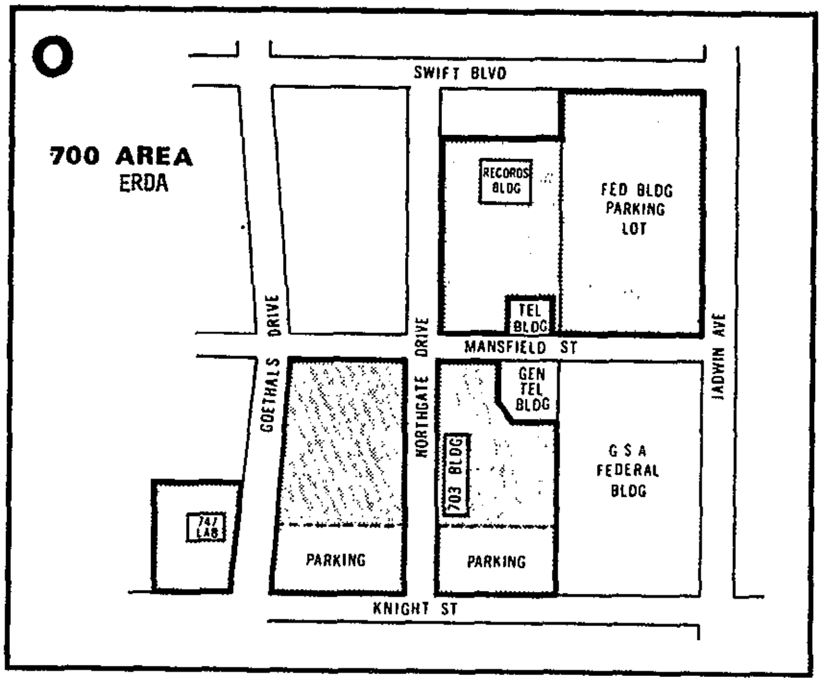

FIGURE II.1-A-1o

p

LEGEND

TOWNSHIP OR RANGE LINE
SECTION LINE, KNOWN AND UNKNOWN
SECTION CORNER LOCATED ... +
SECTION NUMBER ... 32
TOWNSHIP AND RANGE NUMBER ... T12N R28E
UTM COORDINATE SYSTEM ZONE 11 ... 5170000mN
WASHINGTON STATE LAND COORDINATE ... 410.000
HANFORD LAND COORDINATE ... N16658 76. W15746 14
BENCH MARK
U.S RESERVATION BOUNDARY
LEASED PROPERTY LINE
U.S. BUREAU OF RECLAMATION LAND ... U S B R
FENCE, ARID LANDS ECOLOGY RESERVE
FENCE, HANFORD PROJECT
FENCE, AREAS 100, 200, 300 ETC
CONTROLLED ACCESS GATE ... G
RAILROAD, 1 AND 2 TRACK
WATER MAIN, EXPORT WATER ... EW
BURIED PROCESS PIPING CONTAMINATED
DRAINAGE DITCH, CONTAMINATED ... DITCH
DRAINAGE DITCH ... DITCH
INTERMITTENT STREAM
WATER WELL ... WW
LAKE OR POND
RIVER AND DAM
RIVER MILEAGE
BUILDING
BURIAL GROUND, CONTAMINATED
ROAD, STATE ... 240
ROAD, PAVED FOUR LANE
ROAD, PAVED TWO LANE
ROAD, GRAVEL
ROAD, DIRT UNIMPROVED
POWER TRANSMISSION LINE OR EASEMENT
BONNEVILLE POWER ADMINISTRATION ... BPA
BENTON BOUNTY P.U.D. ... BC PUD
PACIFIC POWER & LIGHT ... PP&L
TELEPHONE LINE ... T
TELEPHONE LINE, BURIED ... T
WEATHER STATION - AUTOMATIC

FIGURE II.1-A-1p

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APPENDIX II.1-B .

100 AREA FACILITIES

APPENDIX II.1-B

100 AREA FACILITIES

APPENDIX II.1-B, Part 1

100 Area Maps

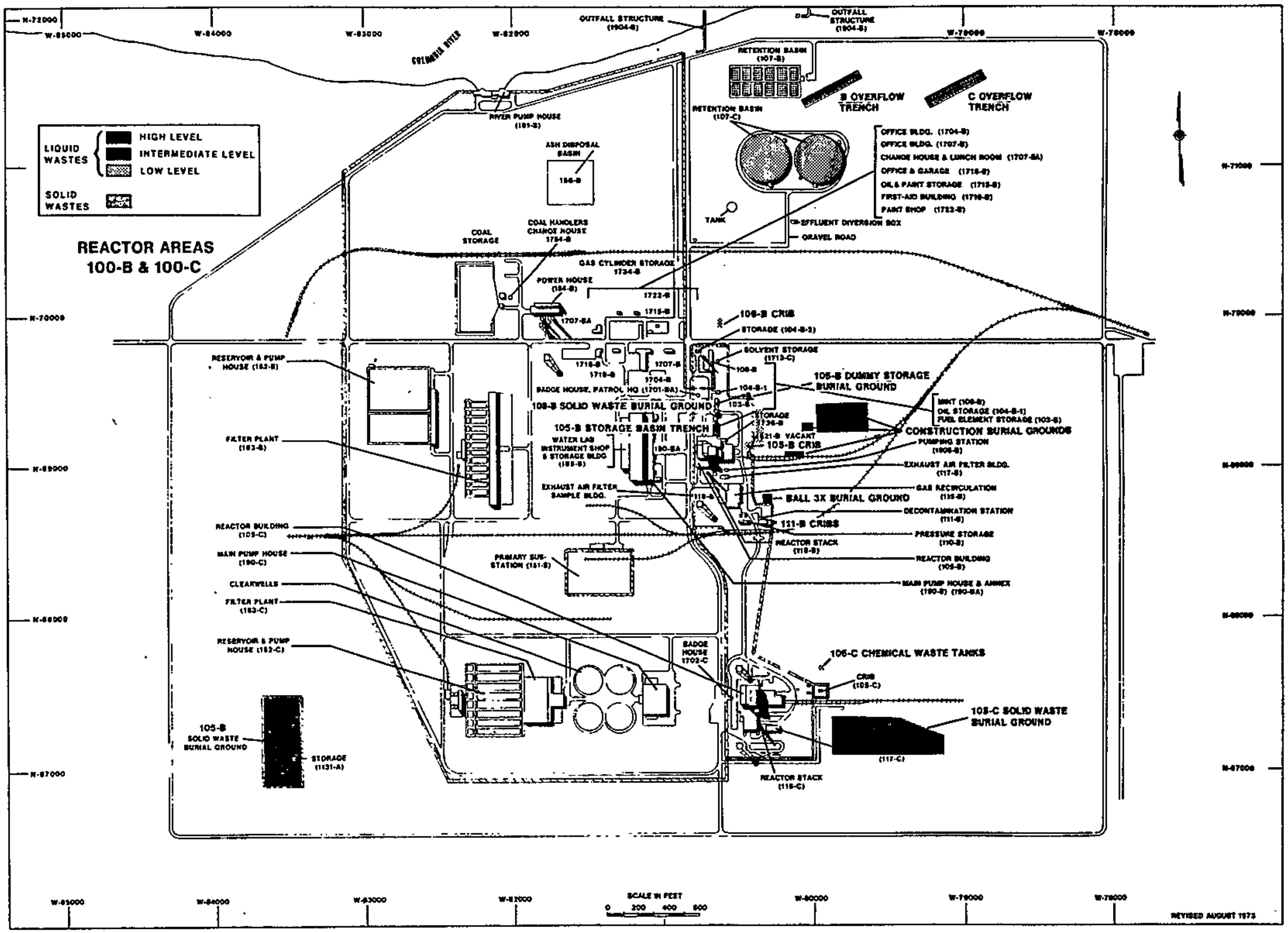

FIGURE II.1-B-1 100-B AREA MAP

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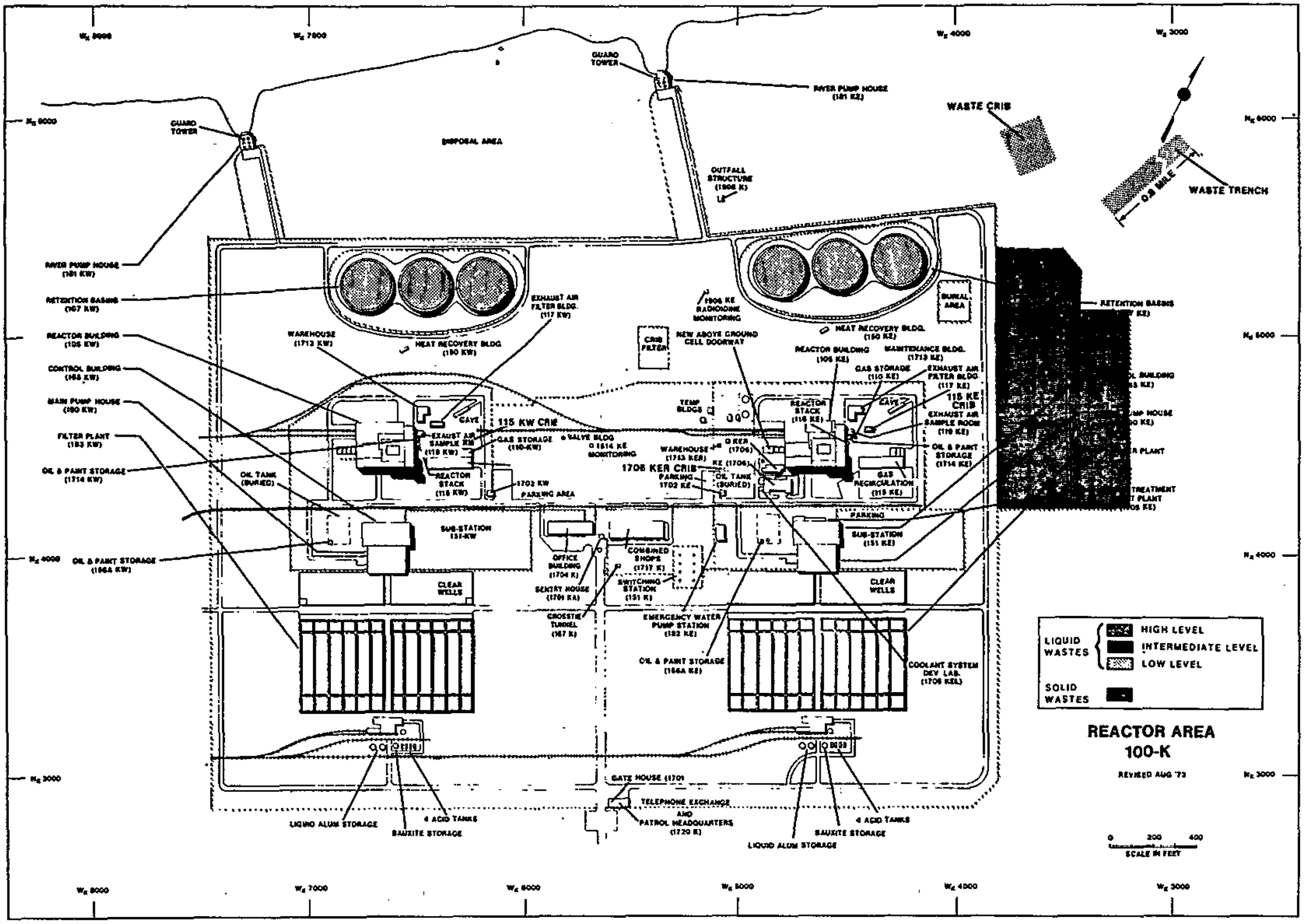

FIGURE II.1-B-2 100-K AREA MAP

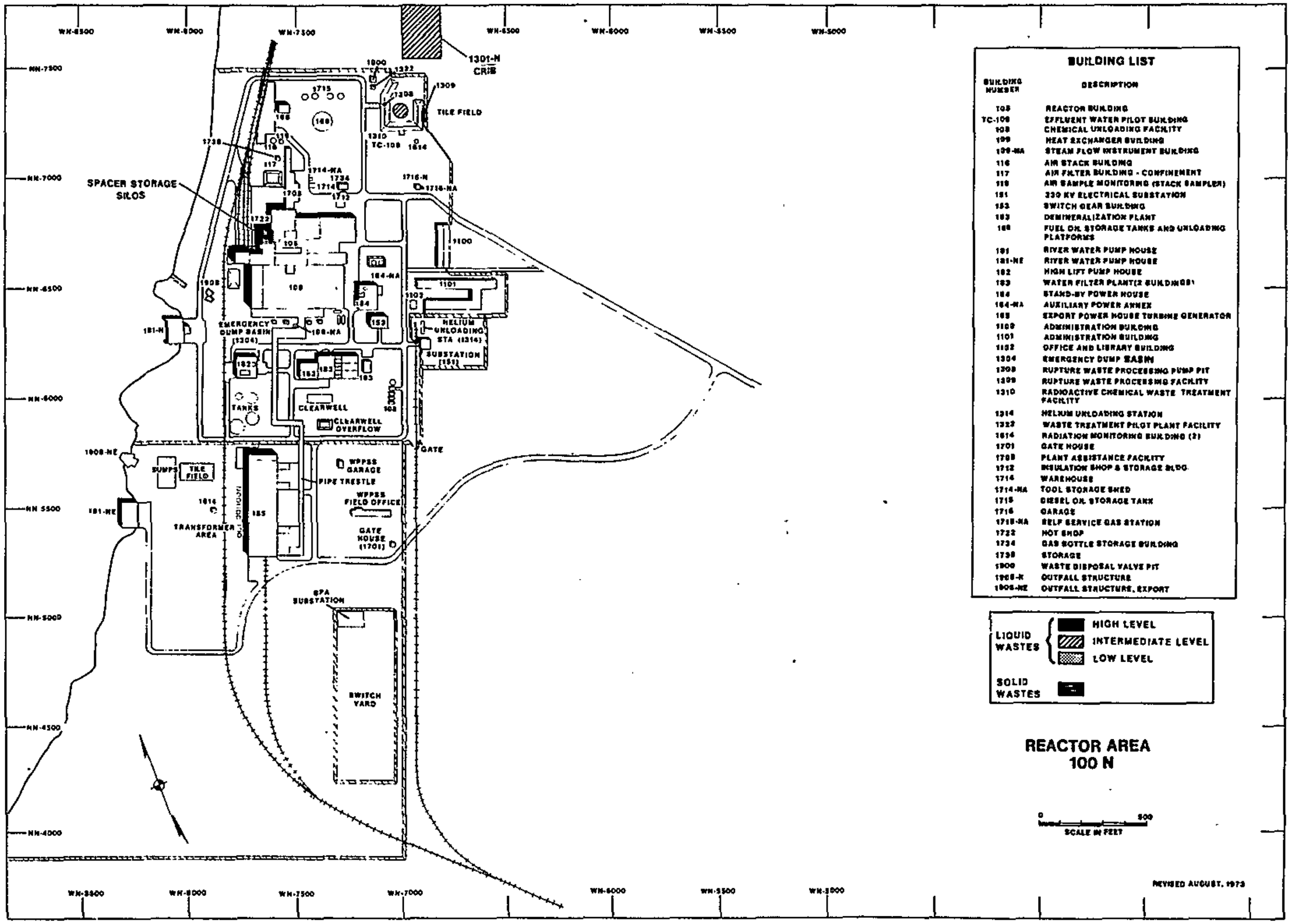

FIGURE II.1-B-3 100-N AREA MAP

9111391105?

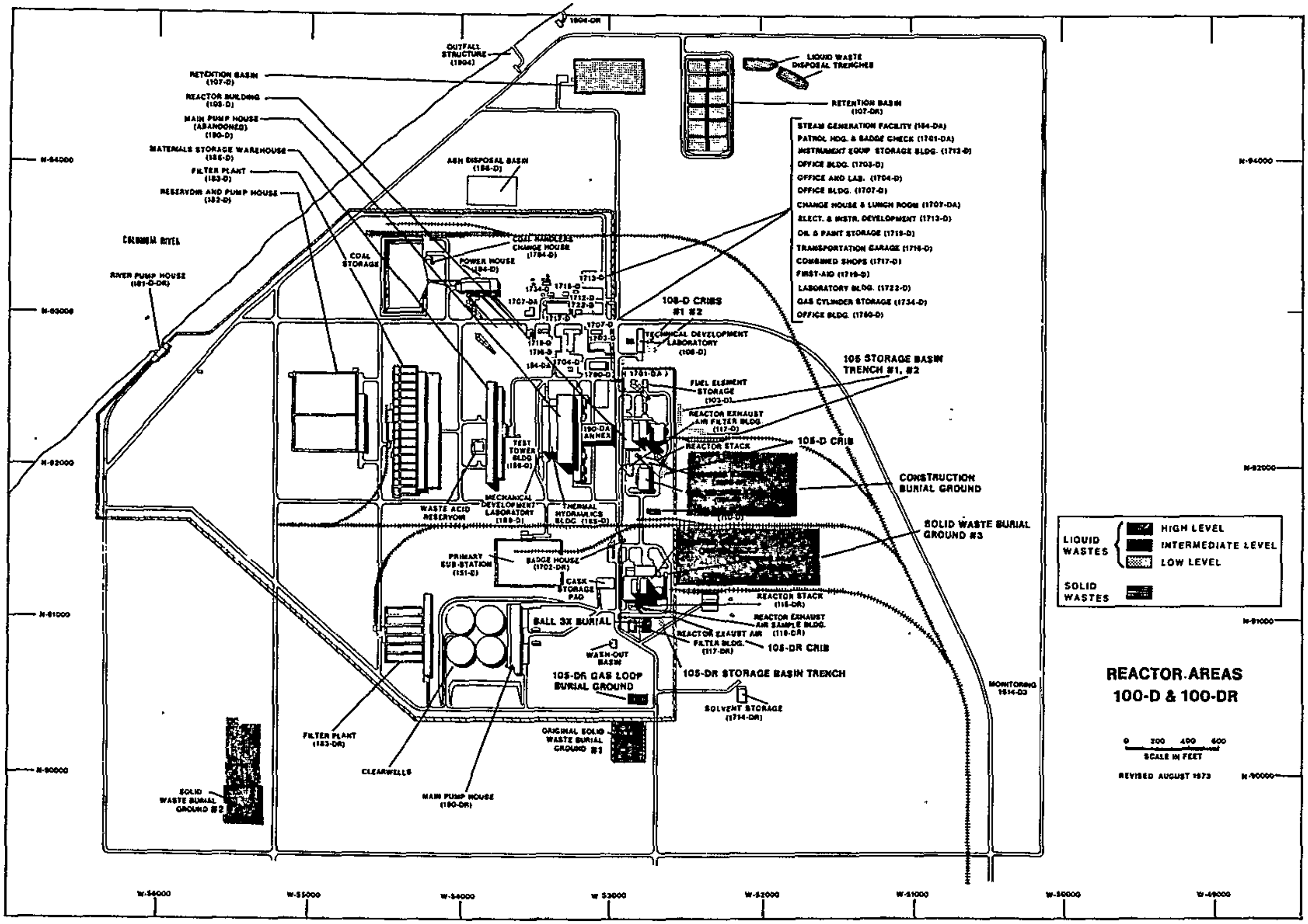

FIGURE II.1-B-4 100-D AREA MAP

9111891053

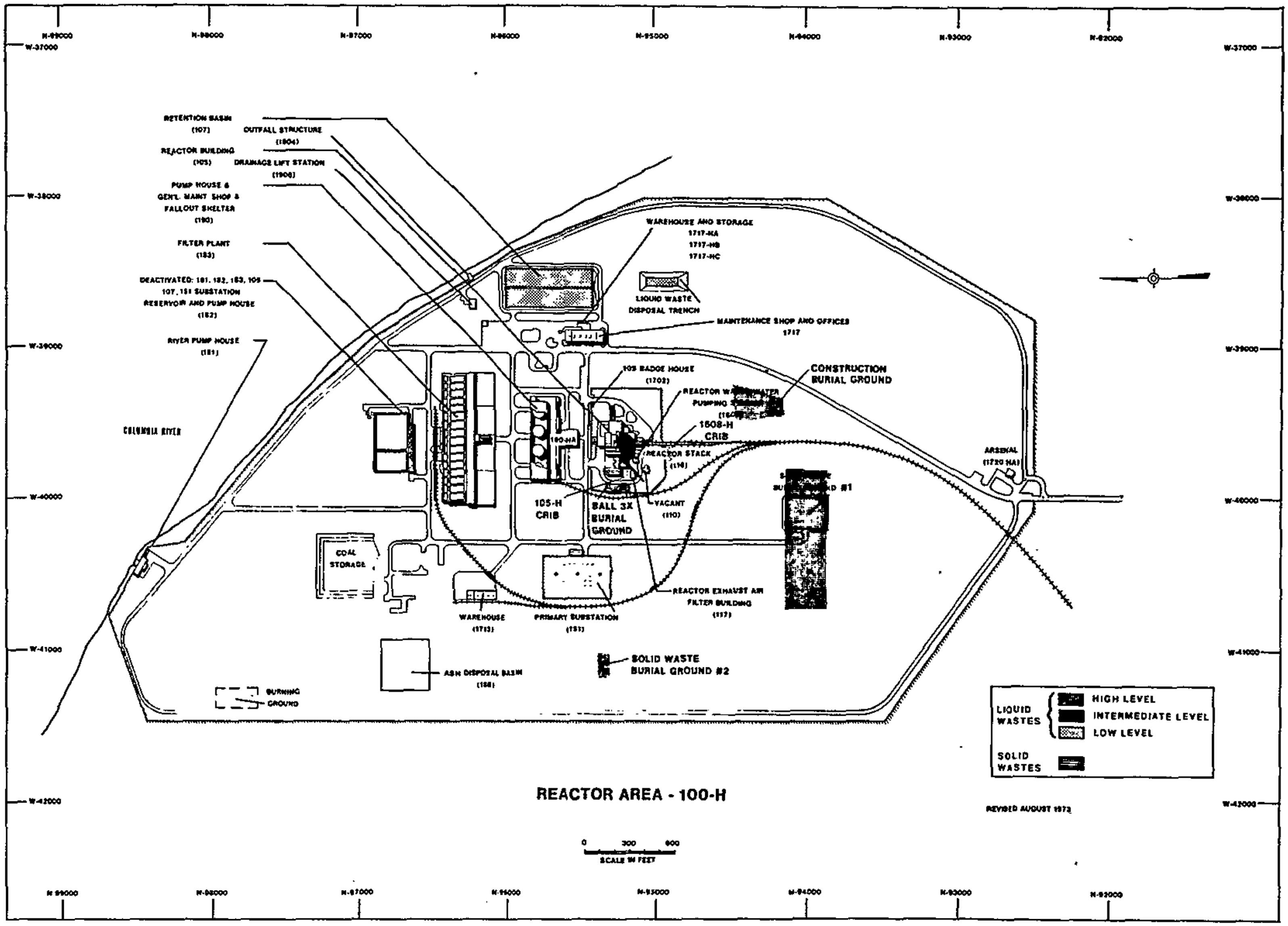

FIGURE II.1-B-5 100-H AREA MAP

9111391 1054

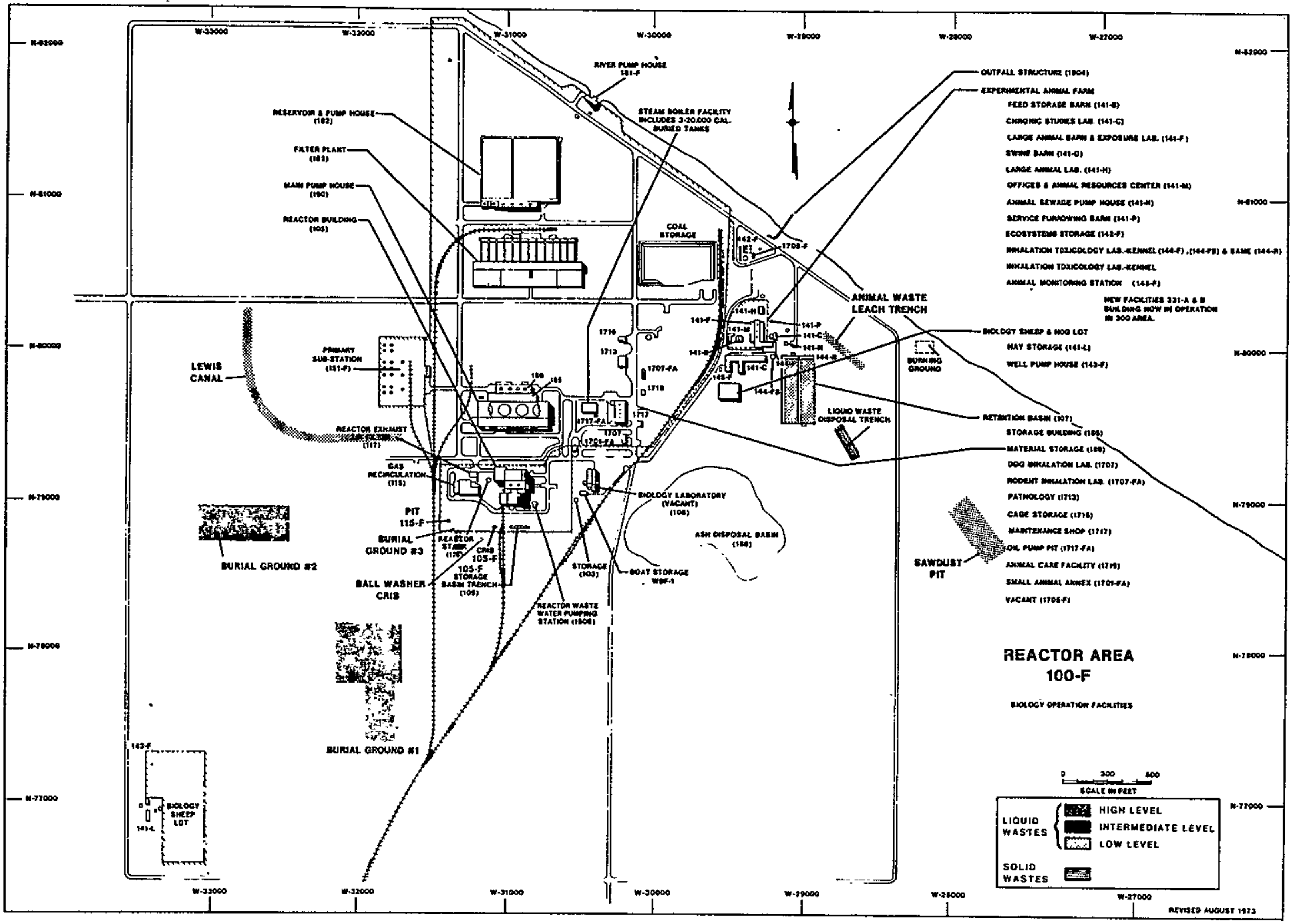

FIGURE II.1-B-6 100-F AREA MAP

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APPENDIX II.1-B, Part 2

Waste Management Facilities,

Cribs and Burial Grounds

TABLE II.1-B-1

WASTE MANAGEMENT FACILITIES, 100-B AREA CRIBS AND BURIAL GROUNDS

Site Designation Current (Past)	Location	Function	Service Dates In Service	Removed From Service
118-C-1 (105-C Burial Ground)	N67316.00/W80005.48 N67316.00/W79748.48 N67249.63/W79494.48 N66920.00/W79494.48 N66920.00/W80005.48	Disposal of miscellaneous radioactive solid waste from 105-C Building.	1953	1969
118-B-1 (105-B Burial Ground)	1100 feet west of 182-C (reservoir and pump house)	Disposal of miscellaneous radioactive solid waste Also received 100-N Area waste.	1944	1974
118-B-2 (Construction Burial Ground No. 1)	350 feet directly east of the 105-B Building. Approx. 30 x 60 feet	Used for the disposal of dry waste from the 107-B basin repairs and for waste from 115-B alterations.	1954	1956
118-B-3 (Construction Burial Ground No. 2)	East of the other construction burial trench	Disposal of waste from effluent line modifications.	1956	1960
118-B-4 (105-B Dummy Storage Burial Ground)	Approx. 200 feet east of 103-B	Six storage tanks were installed below ground for fuel spacer disposal.	1956	1968
118-B-5 (Ball 3X Burial Ground)	150 feet east of 115-B (gas recirculation)	Received irradiated material such as thimbles and step plugs removed from Reactor during the ball 3X work in 1953.	January 1953	1953
118-B-6 (108-B Solid Waste Burial Ground)	350 feet NW of 105-B Reactor	Two concrete pipes 18 ft long and 6 ft in diameter placed vertically in ghe ground for the disposal of dry tritium waste	1950	1953
116-B-1 (107-B Liquid Waste Disposal Trench)	Approx. 200 feet directly east of the 107-B basin	Received effluent water from the B Reactor during outages due to a ruptured fuel element.	1950	1968
116-B-2 (105-B Storage Basin Trench)	250 feet NE of 105-B	This trench was dug after a fuel element was accidentally cut in half in the storage basin. The basin was cleaned by draining the water into this trench.	1946	1946
116-B-3 (105-B Pluto Crib)	100 feet east of 105-B	Received water from isolated tubes containing ruptured fuel elements.	1951	1956
116-B-4 (105-B Dummy Decontamination Disposal Crib)	Approx. 50 feet south of 105-B Crib	Disposal of radioactive waste from decontamination of process dummies and poison which was done on the wash pad.	1957	1968
116-B-5 (108-B Crib)	200 feet north of 1713-C (solvent storage)	Disposal of liquid tritium waste. Only waste of less than 1μCi/cc of tritium was discharged to this crib.	1950	1968
116-B-6 (111-B Cribs (2))	Immediately north and south of the 11 111-B Building	Received radioactive waste from the 111-B Building.	1951	1968
116-B-7 (1904B1 Outfall Structure)	Approx. 600 feet west of the 1904-B-2 outfall structure	Currently used for disposal of water plant treatment waste water.	1944	In Use

5 0 1 9 3 1 1 9

TABLE II.1-B-1 (Continued)

Site Designation Current (Past)	Location	Function	Service Dates In Service	Service Dates Removed From Service
116-B-8 (1904-B2 Outfall Structure)	300 feet north of 107-B retention basin's NE corner	Received and discharged reactor coolant effluent to the Columbia River.	1944	1968
116-C-1 (107-C Liquid Waste Disposal Trench)	1000 feet east of the 107-B retention basin	Received effluent water from the reactor during outages due to a ruptured fuel element.	1952	1968
116-C-2 (105-C Pluto Crib)	275 feet east of the NE corner of 105-C	Received contaminated waste from the dummy decontamination done on the wash pad and water from the 105-C metal examining facilities.	1952	1956
116-C-3 (105-C Chemical Waste Tanks)	300 feet NE of 105-C	Two 27,000-gallon tanks received caustic waste from dejacketing and acid waste from extruding of irradiated fuel elements in the metal examination facility.	1964	1969
116-C-4 (1904-C Outfall Structure)	Approx. 900 feet east of the 1904-B-2 structure identified previously as 116-B-8.	Received and discharged reactor coolant effluent to the Columbia River.	November 1952	1969
107-B (107-B Retention Basin)	N71660/W80560 N71660/W80090 N71430/W80560 N71430/W80090	Retained coolant effluent water from B Reactor for radioactive decay prior to release to the Columbia River.	1944	1968
107-C (107-C Retention Basins)	Center pts. at: N71045/W79970 N71045/W80320	Retained coolant effluent water from C Reactor for radioactive decay prior to release to the Columbia River.	1952	1969

TABLE II.1-B-2

WASTE MANAGEMENT FACILITIES, 100-D AREA CRIBS AND BURIAL GROUNDS

Site Designation Current (Past)	Location	Function	Service Dates In Service	Service Dates Removed From Service
118-D-1 (100-D Burial Ground No. 1)	N90380.0/W53205.0 N90380.0/W52755.0 N90005.0/W52755.0 N90005.0/W53205.0	Contains irradiated dummies, thimbles, rods, gunbarrels and other contaminated solid waste	August 1944	1967
118-D-2 (100-D Burial Ground No. 2)	N90582/W55652.00 N90582.00/W55295.00 N89493.00/W55295.00 N89500.W55652.00	Contains miscellaneous contaminated solid waste Starting in April 1966, 100-N Area solid waste was also buried here	1949	1970
118-D-3 (100-D Burial Ground No. 3)	N91222.61/W52543.30 N91346.35/W52543.13 N91461.09/W52377.65 N91473.66/W51950.73 N91317.73/W51725.01 N91323.05/W51435.73 N91264.50/W51430.74 N91262.57/W51998.27 N91224.19/W52099.07	Miscellaneous contaminated solid wastes and irradiated dummies, splines, rods, thimbles, and gunbarrels. Also used for disposal of 100-N Area solid waste	1956	1973
118-D-4 (Construction Burial Ground)	600 x 200-foot burial area which starts approx. 200 feet east of 115-D (gas recirculation)	Several trenches used for disposal of contaminated material removed from the reactor building.	1953	1967
118-D-5 (Ball 3X Burial)	100 feet south of 105-DR	Thimbles removed from the 105-DR Reactor during the ball 3X work in 1954 were buried in this trench.	1954	1954
118-DR-1 (105-DR Gas Loop Burial Ground)	600 feet south of 105-DR	Irradiated metal assembly from the 105-DR gas loop was buried here.	1963	1964
116-D-1 (105-D Storage Basin Trench)	100 feet east of 105-D	Received contaminated sludge from the 105-D storage basin.	1947	1967
116-D-2 (105-D Pluto Crib)	100 feet east of 115-D (gas recirculation)	Received water from isolated reactor tubes contain ruptured fuel elements.	1950	1956
116-D-3 (108-D Crib No. 1)	Directly east of 108-D (Technical Development Laboratory)	Used for low level fission product waste from a contaminated maintenance shop and cask decontamination.	1951	1967
116-D-4 (108-D Crib No. 2)	100 feet east of 108-D	Used for contaminated waste from maintenance shop and technical laboratory.	1956	1967
116-D-5 (1904-D Outfall Structure)	Approx. 400 feet west of the 107-D retention basin	Received reactor coolant water from the 107-D retention basin. In-service to receive waste from the area process sewer.	1944	In Use
116-DR-1 (107-DR Liquid Waste Disposal Trench No. 1)	100 feet east of 107-DR basin's NE corner	Received effluent water from the 105-D or 105-DR reactor when either had a ruptured fuel element.	1950	1967
116-DR-2 (107-DR Liquid Waste Disposal Trench No. 2)	Directly southeast of 107-DR liquid waste disposal Trench No. 1	A second trench for disposal of effluent from D and DR systems during outages caused by a ruptured fuel element.	1955	1967
116-DR-3 (105-DR Storage Basin Trench)	150 feet east of 117-DR (filter building)	Contaminated sludge removed from 105-DR basin in 1955 was buried here.	1955	1955

TABLE II.1-B-2 (Continued)

Site Designation Current (Past)	Location	Function	Service Dates In Service	Removed From Service
116-DR-4 (105-DR Pluto Crib)	40 feet NE of 105-DR storage basin trench	Received water from isolated tubes containing ruptured fuel elements in 105-DR.	1950	1956
116-DR-5 (1904-DR Outfall Structure)	Approx. location N94651/W53657	Received and discharged reactor coolant effluent to the Columbia River.	1950	1965
107-DR (107-DR Retention Basin)	Approx.: N94680/W52516 N94680/W52219 N94058/W52219 N94058/W52516	Retained reactor coolant effluent water from DR Reactor for radioactive decay prior to release.	1950	1964
107-D (107-D Retention Basin)	N94685/W53250 N94685/W52780 N94455/W52780 N94455/W53250	Retained reactor coolant effluent water from D Reactor for radioactive decay prior to release.	1944	1967

TABLE II.1-B-3

WASTE MANAGEMENT FACILITIES, 100-F AREA CRIBS AND BURIAL GROUNDS

Site Designation Current (Past)	Location	Function	Service Dates In Service	Service Dates Removed From Service
118-F-1 (Burial Ground No. 1 Solid Waste Burial Ground No. 2, and Minor Construction Burial Ground No. 2)	N78071.90/W32200.00 N78178.34/W31800.00 N78178.34/W31600.00 N77671.09/W31600.00 N77671.09/W32200.00	Miscellaneous Radioactive Solid Waste Disposal	1954	1965
118-F-2 (Burial Ground No. 2 Solid Waste Burial Ground No. 1)	N78990.99/W32787.00 N78985.45/W32461.78 N78626.50/W32469.82 N78623.33/W32796.01	Miscellaneous Radioactive Solid Waste Disposal	1945	1965
118-F-3 (Burial Ground No. 3 M.C. Burial Ground No. 1)	N78839.56/W31274.03 N78812.17/W31232.21 N788749.49/W31273.27 N78663.54/W31267.57 N78660.24/W31317.46 N78762.87.W31324.26	Received irradiated waste such as thimbles and step-plugs removed from the 105-F pile during the ball 3X work in 1952.	1952	1952
118-F-4 (115-F Pit)	200 feet south of the 115-F Building	Received silica gel from a dryer room.	1949	1949
118-F-5 (PNL Sawdust Repository)	N78980 N79020 W28990 W27900 N78600 N78690 W27780 W28380	Low-level activity Sawdust from animal pens	1954	In Use
118-F-6 (PNL Solid Waste Burial Ground)	N77780 W31948 N77390 W31720	Animal and laboratory waste	1965	February 1973
116-F-1 (Lewis Canal)	Natural ditch to the west and then north of 105-F (H-1-15244)	Liquid waste from 105-F and 190-F Bldgs, and decontamination waste from 189-F Building.	1953	1965
116-F-2 (107-F Liquid Waste Disposal Trench)	150 feet SE of 107-F Basin's SE corner	Disposal of coolant effluent water containing rupture debris.	1950	1965
116-F-3 (105-F Storage Basin Trench)	130 feet south of 105-F	Received effluent from fuel element rupture. In 1951, sludge from the 105-F storage basin was put in the trench.	1949	1951
116-F-4 (105-F Pluto Crib)	100 feet west of the 105-F storage basin trench described above	Disposal of coolant water from process tubes containing ruptured fuel elements.	1950	1956
116-F-5 (Ball Washer Crib)	250 feet SW of 105-F	Waste from decontamination of boron-steel balls.	1953	1953
116-F-6 (1608-F Liquid Waste Disposal Trench)	50 feet SW of the 105-F storage basin trench described above	Disposal of outage effluent water.	1952	1965
116-F-7 (117-F Crib)	Approx. 200 feet south of the ball washer crib (116-F-5)	Drainage from confinement system's filter seal pits.	1960	1965
116-F-8 (1904-F Outfall Structure)	Approx. 850 feet north of 107-F retention basin	Received and discharged reactor coolant effluent to the Columbia River	1945	1965
107-F (107-F Retention Basin)	N79967.0/W29130.0 N79967.0/W28900.0 N79500.0/W28900.0 N79500.0/W29130.0	Retained coolant effluent water from F Reactor for radioactive decay prior to release to the Columbia River.	1945	1965
116-F-9 (PNL Animal Waste Leach Trench)	N80140 N80110 W28880 W28910 N79860 N79840 W28610 W28640	Receives washdown from animal pens.	1963	In Use

TABLE II.1-B-4

WASTE MANAGEMENT FACILITIES, 100-H AREA CRIBS AND BURIAL GROUNDS

Site Designation Current (Past)	Location	Function	Service Dates In Service	Service Dates Removed From Service
118-H-1 (110-H Burial Ground No. 1)	N94185.11/W40650.34 N94175.44/W39954.21 N93835.44/W39956.31 N93835.44/W40680.19	Contains dummy elements, process tubing, and miscellaneous solid waste	1949	1965
118-H-2 (100-H Burial Ground No. 2 H-1 loop burial area)	N95318.05/W41129.53 N95313.50/W40983.24 N95267.72/W40984.59 N95266.68/W41127.99	Received stainless steel tube removed from the reactor in 1955. During the deactivation of H plant, it was used for disposal of a small amount of contaminated pipe.	1955	1965
118-H-3 (Construction Burial Ground)	Approx. 800 feet south of 105-H Building's SE corner	Received sections of contaminated 16" pipe used as chutes for removal of thimbles from 105-H.	1953	1957
118-H-4 (Ball 3X Burial Ground)	100 feet directly west of 105-H	Irradiated material such as VSR thimbles and guides from 105-H was buried in this trench.	1953	1965
118-H-5 (105-H Thimble Pit)	100 feet directly north of the 1608-H crib (see 1608-H crib's location under 116-H)	A thimble assembly from the "B" experimental hole, 105-H, was buried here.	1953	1953
116-H-1 (107-H Liquid Waste Disposal Trench)	Approx. 350 feet south of the 107-H retention basin	Disposal of coolant effluent from ruptures. Also received water pumped from the 107-H basin during deactivation of the basin.	1952	May 1965
116-H-2 (1608-H Crib and Trench)	Directly south of 105-H and just outside of the cyclone fence which surround the reactor building	Received reactor liquid effluent during the Ball 3X project.	1953	1965
116-H-3 (105-H Dummy Decontamination French Drain - Also known as Perf Decontamination Drain)	200 feet southeast of 105-H	Received the spent acid and rinse water from the 105-H dummy decontamination facility.	1950	1965
116-H-4 (105-H Pluto Crib)	Just off the 105-H Building's southwest corner	Disposal of effluent from tubes containing ruptured fuel elements.	1950	1952
116-H-5 (1904-H Outfall Structure)	N96258.97/W38545.56 N96278.97/W38502.56 N96240.0/W38479.76 N96215.0/W38523.06	Received and discharged reactor coolant effluent to the Columbia River.	1949	1965
107-H (107-H Retention Basin)	N96000.0/W38740.0 N96000.0/W38466 N95368/W38466 N95368/W38740.0	Retained coolant effluent water from H Reactor for radioactive decay prior to release to the Columbia River.	1949	1965
116-H-6 (183-Basin)	Center Pts. At N96030/W39020	Receives the liquid waste from the 300 Area Fuels Fabrication Facility for solar evaporation and recovery of metals.	1973	In Use

TABLE II.1-B-5

WASTE MANAGEMENT FACILITIES, 100-K AREA CRIBS AND BURIAL GROUNDS

Site Designation Current (Past)	Location	Function	Service Dates In Service	Service Dates Removed From Service
118-K (100-K Burial Ground)	N_K5229.50/W_K3930 N_K5229.50/W_K3651.50 N_K5142.20/W_K3580 N_K5032.20/W_K3380.75 N_K4235.00/W_K3379.50 N_K4235.00/W_K3830	Radioactive solid waste from K and N Reactors were buried here.	1955	December 1973
116-K-1 (100-K Crib)	Approx. 200 feet outside of the perimeter fence's north corner	Received reactor coolant water from 107-K retention basins.	1955	1971
116-K-2 (100-K "Mile Long" Trench)	Starts approx. 450 feet outside of the perimeter fence's north corner	Received reactor coolant water from the 107-K retention basins.	1955	1971
116-K-3 (1908-K Outfall Structure)	Center of N_K5650/W_K5036	Received and discharged reactor coolant water from the 107-K retention basins to the Columbia River.	1955	In Use
116-KE-1 (115-KE Crib)	200 feet east of 1713-KE (maintenance building)	Condensate and other waste water from the reactor gas purification system.	1955	1970
116-KE-2 (1706-KER Crib)	180 feet west of 1706-KE building	Waste from the cleanup columns in the 1706-KER loop.	1957	1964
116-KW-1 (115-KW Crib)	Approx. 230 feet east of 105-KW	Condensate and other waste water from the reactor gas purification system.	1955	1971
107-KE (107-KE Retention Basins [3])	Center points: N_K5356.99/W_K4268.02 N_K5328.50/W_K4536.51 N_K5300.00/W_K4805.00	Retained coolant effluent water from KE Reactor for radioactive decay prior to release to the Columbia River.	1955	1971
107-KW (107-KW Retention Basins [3])	Center points: N_K5245/W_K6190 N_K5245/W_K6460 N_K5245/W_K6730	Retained coolant effluent water from KW Reactor for radioactive decay prior to release to the Columbia River.	1955	1970

TABLE II.1-B-6

WASTE MANAGEMENT FACILITIES, 100-N AREA CRIBS AND BURIAL GROUNDS

Site Designation Current (Past)	Location	Function	Service Dates In Service	Service Dates Removed From Service
116-N-1 (1301-N Crib and Trench)	Crib WN5982/NN7004 WN5982/NN7300 WN5856/NN7300 WN5856/NN7004 Trench 1600-foot northeast extension of the above crib	Radioactive effluent streams from 105 and 109-N	Crib 1964 Trench 1965	In Use In Use
116-N-2 (1310-N Waste Storage Area)	Center point at WN5985/NN6775	Collecting tank for N Reactor primary piping decontamination wastes.	1964	In Use
118-N (100-N Area Silos [3])	Area just outside of 105-N Building's NW corner.	Storage of N Reactor fuel spacer elements	1963 (one) 1967 (two)	In Use

APPENDIX II.1-B, Part 3

Estimated Radioactive Material Inventories

TABLE II.1-B-7

ESTIMATED INVENTORIES IN REACTOR FACILITIES THROUGH 1972

	Inventory - (Curies)
100-B	
2 Reactor Blocks	13,000 (^{60}Co)
2 Metal Storage Basins	20 (^{90}Sr, ^{137}Cs, ^{239}Pu)
3 107 Basins and Soil	150 (^{152}Eu, ^{239}Pu)
100-D	
2 Reactor Blocks	8,500 (^{60}Co)
2 Metal Storage Basins	20 (^{90}Sr, ^{137}Cs, ^{239}Pu)
2 107 Basins and Soil	100 (^{152}Eu, ^{239}Pu)
100-F	
1 Reactor Block	4,300 (^{60}Co)
1 Metal Storage Basin	10 (^{90}Sr, ^{137}Cs, ^{239}Pu)
1 107 Basin and Soil	50 (^{152}Eu, ^{239}Pu)
100-H	
1 Reactor Block	4,300 (^{60}Co)
1 Metal Storage Basin	10 (^{90}Sr, ^{137}Cs, ^{239}Pu)
1 107 Basin and Soil	50 (^{152}Eu, ^{239}Pu)
100-K	
2 Reactor Blocks	26,000 (^{60}Co)
2 Metal Storage Basins	100 (^{90}Sr, ^{137}Cs, ^{239}Pu)
6 107 Basins and Soil	300 (^{152}Eu, ^{239}Pu)
100-N	
1 Reactor Block	18,000 (^{60}Co)
Spacer Storage	150,000 (^{59}Fe)
	2,000 (^{60}Co)
TOTAL (Ci)	160 (^{90}Sr, ^{137}Cs, ^{239}Pu)
	650 (^{152}Eu, ^{239}Pu)
	76,100 (^{60}Co)
	150,000 (^{59}Fe)

NOTE: ^{14}C data in the reactors and reactor systems are insufficient to quantify at this time.

TABLE II.1-B-8

100 AREAS APPROXIMATE INVENTORIES CRIBS AND BURIAL GROUNDS THROUGH 1972[a]

Location	Radioactive Inventory Half-Life <1 Year, Ci	Half-Life >1 Year, Ci
100-B		
Solid Waste (Production)	3,500 (^{54}Mn, ^{95}Zr)	3,500 (^{60}Co)
100-D		
Solid Waste (Production)		4,000 (^{60}Co)
100-F		
Solid Waste (Production)		1,900 (^{60}Co)
Solid Waste (Research)		15 (^{90}Sr)
Sawdust Repository (Research)		15 (^{90}Sr) 0.3 (^{239}Pu)
Animal Waste Leaching Trench (Research)		4 (^{90}Sr) 0.08 (^{239}Pu)
100-H		
Solid Waste (Production)		3,500 (^{60}Co)
100-K		
Solid Waste (Production)	1,000 (^{65}Zn)	13,000 (^{60}Co)

		Ci
TOTAL	^{60}Co	25,900
	^{90}Sr	34
	^{239}Pu	0.38
	^{65}Zn	1,000
	^{54}Mn, ^{95}Zn	3,500

(a) Except for 100-N Area Crib.

TABLE II.1-B-9

ESTIMATED INPUT TO THE 100-N AREA CRIB THROUGH 1972

	Crib Inventory, Ci
^{32}P	15
^{51}Cr	40
^{54}Mn	800
^{58}Co	14
^{59}Fe	80
^{60}Co	2000
^{89}Sr	10
^{90}Sr	50
^{95}Zr	150
^{99}Mo	20
^{106}Ru	80
^{131}I	6
^{134}Cs	90
^{137}Cs	350
^{140}Ba	20
TOTAL	3700

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APPENDIX II.1-B, Part 4

Radioactive Material Releases - 1972

TABLE II.1-B-10

100-N RADIOACTIVE MATERIAL RELEASES TO THE COLUMBIA RIVER - 1972

Via 102-inch Discharge Line[a]

Gross Volume	Nuclide	Curies	Conc. (μCi/ml)
3.7×10^{11} ℓ	^{140}BaLa	10	2.7×10^{-8}
	^{58}Co	2	5.4×10^{-9}
	^{60}Co	20	5.4×10^{-8}
	^{51}Cr	20	5.4×10^{-8}
	^{134}Cs	0.5	1.4×10^{-9}
	^{137}Cs	5	1.4×10^{-8}
	^{59}Fe	10	2.7×10^{-8}
	^{131}I	40	1.1×10^{-7}
	^{54}Mn	40	1.1×10^{-7}
	^{56}Mn	600	1.6×10^{-6}
	^{99}Mo	20	5.4×10^{-8}
	^{24}Na	500	1.4×10^{-6}
	^{239}Np	90	2.4×10^{-7}
	^{124}Sb	0.8	2.2×10^{-9}
	^{95}ZrNb	8	2.2×10^{-8}
	^{103}Ru	0.4	1.1×10^{-9}
	^{106}Ru	4	1.1×10^{-8}
	^{133}Xe	10	2.7×10^{-8}

Via Seepage Springs on Riverbank

Gross Volume	Nuclide	Curies	Conc. (μCi/ml)
2.8×10^{9} ℓ	^{140}BaLa	0.5	1.8×10^{-7}
	^{60}Co	0.01	3.6×10^{-9}
	^{51}Cr	5.3	1.9×10^{-6}
	^{137}Cs	0.05	1.8×10^{-8}
	^{3}H	7000	2.5×10^{-3}
	^{131}I	1.9	6.8×10^{-7}
	^{99}Mo	1.1	3.9×10^{-7}
	^{89}Sr	0.05	1.8×10^{-8}
	^{90}Sr	0.95	3.4×10^{-7}

(a) Significant reduction of the activity in this stream is expected following the post-1972 rerouting of radioactive liquid waste streams feeding into the 102-inch discharge line.

TABLE II.1-B-11

GASEOUS RADIOACTIVE MATERIAL RELEASE - 1972

N Reactor

Volume 1.9×10^{15}ml	^{41}Ar	^{3}H	^{131}I	^{133}I
Total Release (Ci)	1×10^{5}	2.7×10^{1}	1.3×10^{-2}	0.5
Avg. Release Rate (Ci/day)	270	0.07	3.6×10^{-5}	1.4×10^{-3}
Avg. Concentration (μCi/ml)	5.2×10^{-5}	1.4×10^{-8}	6.8×10^{-12}	2.6×10^{-10}

Plutonium Inhalation Laboratory--144-F

	Total Alpha[a]	Total Beta[b]
Volume 2.4×0.09 (ft^3)		
Ave. Concentration (μCi/ml)	$<5.4 \times 10^{-15}$	$<6.6 \times 10^{-14}$
Ave. Release Rate (μCi/wk)	<0.007	<0.087
Max. Release Rate (μCi/wk)	<0.029	<0.13
Total Release (μCi)	<0.37	<4.5

(a) Analyzed as though alpha activity were due entirely to ^{239}Pu.
(b) Aanlyzed as though beta activity were due entirely to ^{90}Sr.

APPENDIX II.1-B, Part 4

Radioactive Material Releases - 1972

TABLE II.1-B-10

100-N RADIOACTIVE MATERIAL RELEASES TO THE COLUMBIA RIVER - 1972

Via 102-inch Discharge Line[(a)]				Via Seepage Springs on Riverbank			
Gross Volume	Nuclide	Curies	Conc. (μCi/ml)	Gross Volume	Nuclide	Curies	Conc. (μCi/ml)
3.7×10^{11} ℓ	^{140}BaLa	10	2.7×10^{-8}	2.8×10^{9} ℓ	^{140}BaLa	0.5	1.8×10^{-7}
	^{58}Co	2	5.4×10^{-9}		^{60}Co	0.01	3.6×10^{-9}
	^{60}Co	20	5.4×10^{-8}		^{51}Cr	5.3	1.9×10^{-6}
	^{51}Cr	20	5.4×10^{-8}		^{137}Cs	0.05	1.8×10^{-8}
	^{134}Cs	0.5	1.4×10^{-9}		^{3}H	7000	2.5×10^{-3}
	^{137}Cs	5	1.4×10^{-8}		^{131}I	1.9	6.8×10^{-7}
	^{59}Fe	10	2.7×10^{-8}		^{99}Mo	1.1	3.9×10^{-7}
	^{131}I	40	1.1×10^{-7}		^{89}Sr	0.05	1.8×10^{-8}
	^{54}Mn	40	1.1×10^{-7}		^{90}Sr	0.95	3.4×10^{-7}
	^{56}Mn	600	1.6×10^{-6}				
	^{99}Mo	20	5.4×10^{-8}				
	^{24}Na	500	1.4×10^{-6}				
	^{239}Np	90	2.4×10^{-7}				
	^{124}Sb	0.8	2.2×10^{-9}				
	^{95}ZrNb	8	2.2×10^{-8}				
	^{103}Ru	0.4	1.1×10^{-9}				
	^{106}Ru	4	1.1×10^{-8}				
	^{133}Xe	10	2.7×10^{-8}				

(a) Significant reduction of the activity in this stream is expected following the post-1972 rerouting of radioactive liquid waste streams feeding into the 102-inch discharge line.

TABLE II.1-B-11

GASEOUS RADIOACTIVE MATERIAL RELEASE - 1972

N Reactor

Volume 1.9×10^{15} ml	^{41}Ar	^{3}H	^{131}I	^{133}I
Total Release (Ci)	1×10^{5}	2.7×10^{1}	1.3×10^{-2}	0.5
Avg. Release Rate (Ci/day)	270	0.07	3.6×10^{-5}	1.4×10^{-3}
Avg. Concentration (μCi/ml)	5.2×10^{-5}	1.4×10^{-8}	6.8×10^{-12}	2.6×10^{-10}

Plutonium Inhalation Laboratory--144-F

	Total Alpha[(a)]	Total Beta[(b)]
Volume 2.4×0.09 (ft^3)		
Ave. Concentration (μCi/ml)	$<5.4 \times 10^{-15}$	$<6.6 \times 10^{-14}$
Ave. Release Rate (μCi/wk)	<0.007	<0.087
Max. Release Rate (μCi/wk)	<0.029	<0.13
Total Release (μCi)	<0.37	<4.5

(a) Analyzed as though alpha activity were due entirely to ^{239}Pu.
(b) Aanlyzed as though beta activity were due entirely to ^{90}Sr.

APPENDIX II.1-B, Part 5

Unplanned Releases

TABLE II.1-B-12

100 AREAS UNPLANNED RELEASES

DATE	BLDG.	DESCRIPTION	NUCLIDE & AMOUNT
6-27-72	1310-N	Radioactive chemical waste handling facility piping leak. Approx. 90,000 gallons of radioactive wastes discharged to ground.	35 Ci, of which 26 Ci were ^{60}Co.
3-13-71	141-C 100-F	The main sewer lines from 141-C to 141-N Bldgs. became plugged and spread contamination on the ground. Area 20' x 40' x 40' 8000-20,000 c/m ∿. Area stabilized with clean gravel cover.	∿ 0.005 Ci ^{90}Sr
5-23-68	105-KE	Release to river. 2000 Ci mixed activation products.	2000 Ci mixed F.P.
2-11-66	105-KW	Fuel element failure, releasing 600 curies of I-131 to river.	600 Ci ^{131}I
1-17-64	107-F	High wind spread particulate contamination out of 107-F basin while it was dry for repairs. Particles to 80,000 c/m. Particles with > 5000 c/m removed.	Mixed activation products
7-11-63	107-KW	Northeast wind spread particulate contamination out of KW Basins while they were dry for repairs. Particles from 1000-8000 c/m. No contamination detected off project. Involved area controlled as radiation zone, contaminants seated by water flush and decayed.	Mixed activation products
6-7-63	107-KE	Wind spread particulate contamination out of KE Basins which were nearly dry due to extended reactor shutdown. Maximum particle inside limited area fence was 300 mrads/hr. Maximum outside fence was 20,000 c/m. No contamination detected off project. Particles > 5000 c/m recovered.	Mixed activation products
4-29-59	105-KW	During discharge, a small fraction of a ruptured fuel element burned and particulate contamination was released to the atmosphere via the ventilation stack. Widely dispersed particulates detected on Wahluke Slope. Five particles ranged from 3000 to 60,000 cpm. Control monitoring plots established to determine migration of low activity particles; those particles > 5000 c/m recovered.	1.3 Ci mixed F.P.
12-6-57	107-C	Wind spread particulate contamination from C Basin which was dry for repair. General contamination of 3000 to 6000 c/m in a fan shape area to the east and southeast with a maximum of 65 mrad/hr. Area posted as Radiation Zone, seasonal rains fixed contaminant in soil.	Mixed activation products
9-27-57	105-C	Ruptured fuel element burned for 10-min at reactor discharge face. No deposition of radioactivity was found on the ground outside 105-C exclusion area although an estimated 4 Ci of filterable gross beta activity was emitted from 105-C stack.	4 Ci F.P.
4-23-57	107-C	Wind spread particulate contamination from C Basin which was dry for repair work. Ground contamination of 5000 to 80,000 c/m extended in a fan shape east. A later wind shifted the contamination to the northeast with readings up to 5000 c/m on May 2, 3 and 6. Area flushed repeatedly with water to immobilize particulates.	Mixed activation products
2-21-57	107-D	Wind spread particulates contamination out of 107-D Basin while it was dry for repair work. Maximum contamination was 40 mrad/hr with 0-8 particles per 100 ft^2 inside 100-D area fences. No significant contamination was found outside 100-D Area or on Wahluke slope. Particles > 5000 c/m recovered.	Mixed activation products
9-17-56	105-C	A fuel element burned for 6 minutes at the reactor discharge face resulting in stack emission of particulates. Contamination levels on ground were 5000 to 30,000 c/m. Maximum particle 350 mrad/hr. Area involved was decontaminated.	^{239}Np and mixed F.P.
5-15-56	107-H	Swallows used mud from 107-H liquid waste trench for nest building. The contaminated mud was being dropped around the 100-H water towers and at scattered locations over the flight path to White Bluffs across the Columbia River. Concentrations ranged from 0-6 particles per 100 ft^2 with a maximum reading of 150 mrad/hr. Nests removed at the building sites, waste trench exposed mud covered with clean gravel.	

TABLE II.1-B-12 (Continued)

DATE	BLDG.	DESCRIPTION	NUCLIDE & AMOUNT
11-1-55	105-H	Ruptured fuel element burned briefly during discharge resulting in a stack emission and discharge of 1000-2000Ci of mixed fission products to the basins. Ground level contamination was up to 12 particles per 100 ft² ranging from 1000 to 10,000 c/m and a maximum level of 700 mrad/hr. The contamination spread south over about seven square miles. Contaminated soil removed and disposed of to burial trench.	0.8 Ci Barium, Rare Earths, Yttrium
5-23-55	107-F	Water overflowed 107-F Basin after baffles broke loose and plugged the outlet. General contamination around the basin and along a narrow path to the river ranged from 20,000 to 60,000 c/m with a maximum of 350 mrad/hr. Baffle boards carried into the river read 14 mrad/hr. Area covered with clean soil.	Mixed activation products
5-3-55	105-H	Removal of two ruptured fuel elements from the reactor resulted in release of particulate radioactivity with concentrations as high as 20 particles per 100 ft² in the northeast corner of 100-H Area. Six particles were detected in 10,000 ft² along the Wahluke Slope road. Particles were removed as located.	0.1 Ci gross Beta
3-26-54	107-C	Ground level contamination occurred while 107-C Basin was empty for repair. Particulate contamination up to 50 mrad/hr covered 20% of 100-B Area. No particles above 10 mrad/hr were found outside 100-B Area. Roadways were water flushed and the concentrated activity was removed to the burial ground.	50% Rare Earths 5% $^{103,\,106}Ru$ Traces of Sr, U, Pu
2-25-54	107-B	A break in 107-B Basin flooded an area around the basin with water reading up to 13 mrad/hr. Beta radioactivity of the mud was 10^{-4} to 10^{-2} μCi/gm. Contamination was confined to the vicinity of the basin. The area involved was covered with clean gravel.	Mixed activation products
12-4-51	P-11	Fire occurred in contaminated waste storage area of a remotely located research facility. Fire spread to chemical laboratory and exhaust filters. Contamination was confined to immediate vicinity of laboratory. Contaminated soil surfaces were covered with sand.	~ 0.7 Ci Pu

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APPENDIX II.1-C

200 AREA FACILITIES

APPENDIX II.1-C

200 AREA FACILITIES

APPENDIX II.1-C, Part 1

200 Area Maps

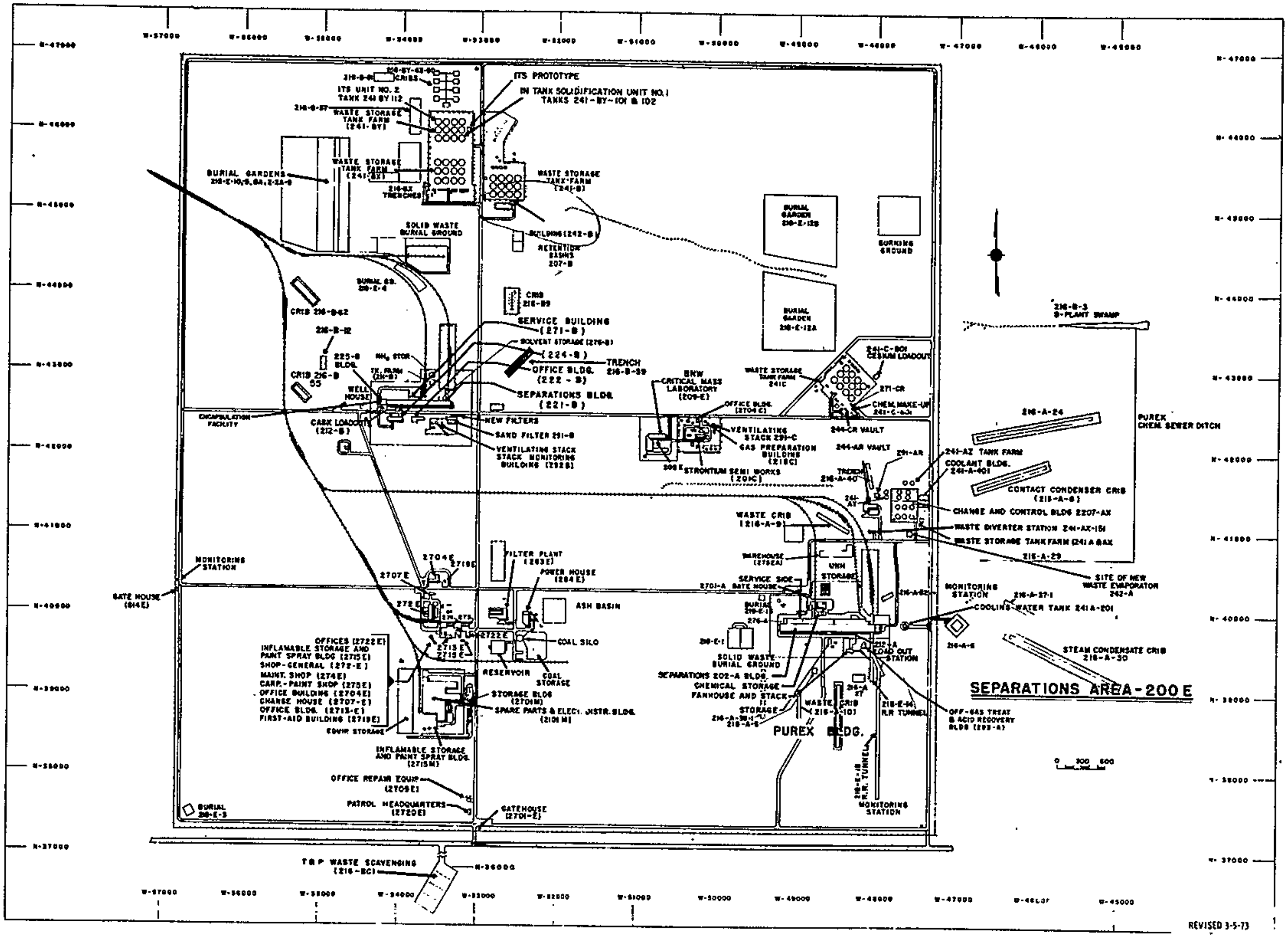

FIGURE II.1-C-1 DETAILED MAP OF 200 EAST AREA

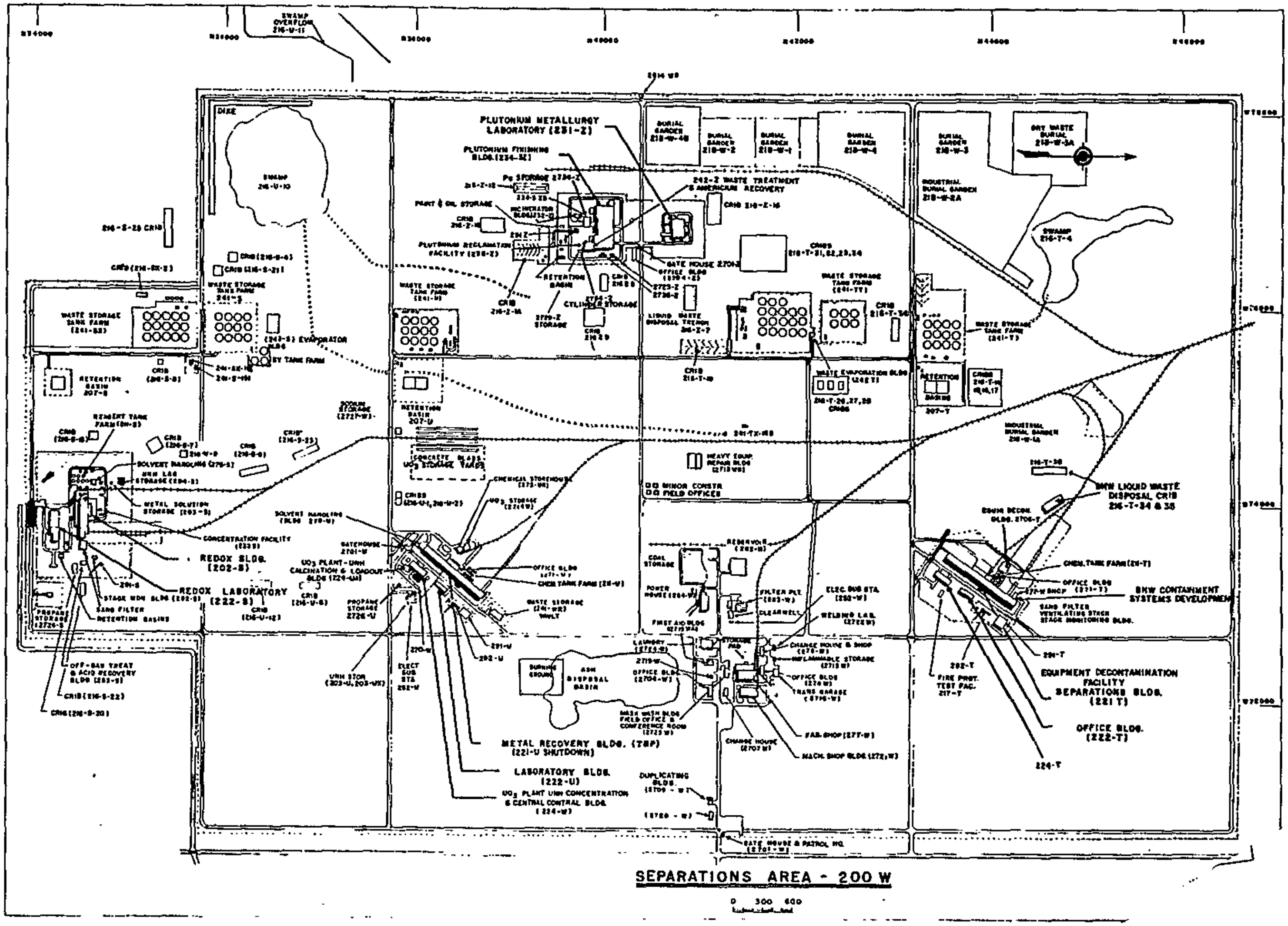

FIGURE II.1-C-2 DETAILED MAP OF 200 WEST AREA

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APPENDIX II.1-C, Part 2

Waste Management Facilities

Tanks, Cribs, Ponds, and Burial Grounds

TABLE II.1-C-1

200 EAST AREA TANK FARMS AND FACILITIES

Number	Description
"A" Tank Farm Facilities	
241-A	6 Tanks: 10^6 gal each
241-AX	4 Tanks: 10^6 gal each
241-AY	2 Tanks: 10^6 gal each
241-AZ	2 Tanks: 10^6 gal each; (one complete, one under construction
241-A-201	Emergency Cooling Water Storage Tank
241-A-271	Control House
241-A-401	Condenser House
241-A-431	Ventilation House (Standby)
241-A-701	Compressor House
241-A-702	Fan House
241-AX-801-A	AX Farm Control House North
241-AX-801-B	AX Farm Control House South
241-AX-801-C	AX Farm Control House (Diverter House)
241-AY-801	AY Farm Instrument House
2707-AX	Change House
241-A-152	Diversion Box
241-A-153	Transfer Box
	Other structures include Ion Exchange Column, Cooling Tower, Contact Condensers, Isolation Jumper Pit, Emergency Water Well
241-AX-153	Valve Pit
241-AX-151,152	Diverter Stations
241-AZ-151	Diverter Stations
241-AY-152	Sluice Transfer Box
241-AZ-152	Sluice Transfer Box
241-AY-151	Pump Out Pit
241-A-501	Condensate Valve Pit
241-AX-501	Condensate Valve Pit
241-AY-501	Condensate Valve Pit
241-AZ-501	Condensate Valve Pit
241-A-417	Condensate Receiver and Pump Pit
"AR Vault" Facilities	
244-AR	Current Acid Waste Storage and Sludge Processing Vault
2707-AR	Change House
2714-AR	General Storage
2802-AR	Steam Distribution Piping
2901-AR	Water Storage Piping
2904-AR	Process Sewer System
291-AR	Exhaust Air Filter, Stack and Plenum
2708-AR	Laundry Storage
244-AR-701	Emergency Generator Bldg.

TABLE II.1-C-1 (Continued)

Number	Description
"B" Tank Farm Facilities	
241-B	12 Tanks: 533,000 gal each 4 Tanks: 55,000 gal each
241-BX	12 Tanks: 533,000 gal each
241-BY	12 Tanks: 758,000 gal each
241-BR, BXR, BYR	Waste Metal Recovery Facilities
241-B-701	Compressor House
241-BY-254	ITS No. 2 Control and Compressor House
241-BY-301	ITS No. 1 Control House
241-BY-302	ITS No. 1 Compressor House
2707-BY	Change House
242-B	Aerosol Release, Corrosion Test Facility
252-BY	Substation (13.8 kW)
244-BXR	Waste Disposal Vault (Underground)
Diversion Boxes	
241-B-151,152,153	
242-B-152	
241-B-252	
241-BR-152	
241-BX-153,155	
241-BXR-151,152,153	
241-BYR-152,153,154	
"C" Tank Farm Facilities	
241-C	12 Tanks: 533,000 gal each 4 Tanks: 55,000 gal each
241-CR-271	Control House and Office
241-C-801	Cesium Load-Out Building
291-CR	Stack and Filter
244-CR	Waste Disposal Vault (Underground)
241-C-151,152,252 241-CR-151,152,153	Diversion Boxes

Steel Tank Liner Specification[a]

Farm	Steel Specification
241-A	ASTM A283 Grade C
241-AX	ASTM A201 Grade C
241-AY	ASTM A515 Grade 60
241-AZ	ASTM A515 Grade 60
241-B	ASTM A283 Grade C
241-BX	ASTM A283 Grade C
241-BY	ASTM A283 Grade C
241-C	ASTM A283 Grade C

AY and AZ constructed liners were heat treated in place for stress relief.

(a) Equivalent current specifications for materials used.

TABLE II.1-C-2

200 WEST AREA TANK FARMS AND FACILITIES

Number	Description
"S" Tank Farm Facilities	
241-S	12 Tanks: 758,000 gal each
241-SX	15 Tanks: 10^6 gal each
241-SY	3 tanks: 10^6 gal each (under construction)
241-SX-281	Emergency Cooling Water Pump House
241-SX-401	Condenser House (North)
241-SX-402	Condenser House (South)
241-SX-701	Compressor House
241-SX-271	Control House
2707-SX	Change House
242-S	Evaporator Building
2901-SX	Water Storage Tank
2902-SX	Water Storage Tank
242-S-702	Ventilation Turbine
242-S-272	Maintenance Shop
241-S-151	Diversion Box
241-SX-151,152	Diversion Box
"T" Tank Farm Facility	
241-T	12 Tanks: 533,000 gal each 4 Tanks: 55,000 gal each
241-TX	18 Tanks: 758,000 gal each
241-TY	6 Tanks: 758,000 gal each
241-T-601	Chemical Makeup
241-TR, TXR	Waste Metal Recovery Facilities
242-T	Waste Evaporator
244-TXR	Waste Disposal Vault (Underground)
241-T-701	Compressor House
242-TA	Vault
242-TB	Ventilation and Filter Bldg.
241-T-151,152,153	Diversion Boxes
242-T-151,152	Diversion Boxes
241-TX-153,154,155	Diversion Boxes
241-TY-153	Diversion Boxes
241-TR-152,153	Diversion Boxes
241-TXR-151,152,153	Diversion Boxes

TABLE II.1-C-2 (Continued)

Number	Description
"U" Tank Farm Facilities	
241-U	12 Tanks: 530,000 gal each 4 Tanks: 55,000 gal each
241-UR	Waste Metal Recovery Facilities
271-U-271	U Farm Control House
244-UR	Waste Disposal Vault
241-U-701	Compressor House
241-U-151,152,153,252	Diversion Boxes
241-UR-151,152,153,154	Diversion Boxes
241-UX-154	Diversion Boxes
241-WR	Thorium Nitrate Storage Vault

Steel Tank Liner Specifications[a]

Farm	Steel Specification
241-S	ASTM A283 Grade C
241-SX	ASTM A283 Grade C
241-T	ASTM A283 Grade C
241-TX	ASTM A283 Grade C
241-TY	ASTM A283 Grade C
241-U	ASTM A283 Grade C
241-SY	ASTM A516 Grade 60[b]

(a) Equivalent current specifications for materials used.
(b) SY constructed liners were heat treated in place for stress relief.

TABLE II.1-C-3

200 EAST AREA LIQUID WASTE DISPOSAL SITES
(Cribs, Ponds, Ditches, Trenches, Pits, French Drains, etc.)

Type of Construction	Number	Description	Bottom Area ft^2	Use Dates From	Use Dates To	Status
PUREX PLANT - 244 SR Vault, A, AX, AY Tank Farms						
C	216-A-1	Startup Waste	900	11/55	12/55	Terminated
C	216-A-2	Organic Waste	400	5/56	1/63	Terminated - Replaced by A-31
C	216-A-3	203-A Silica Gel Waste	400	3/56	1/73	Inactive
C	216-A-4	Laboratory and Stack Drain	400	12/55	12/58	Terminated - Replaced by A-21
C	216-A-5	Process Condensate	1,225	11/55	11/61	Inactive - Replaced by A-10
C	216-A-6	Steam Condensate	10,000	11/55	1/70	Inactive
C	216-A-7	Catch Tank Pump Pit Drain	100	11/55	-	Active
C	216-A-8	Tank Farm Condenser Effluent	17,600	11/55	-	Active
C	216-A-9	Fractionator Condenser Effluent and N Reactor Decontamination Waste	8,400	3/56	8/69	Terminated
C	216-A-10	Process Condensate	12,375	11/61	-	Active
FD	216-A-11	Trap Pit No. 1 Drain (French Dr)	30 in. diam	11/55	-	Active
FD	216-A-12	Trap Pit No. 3 Drain (French Dr)	30 in. diam	11/55	-	Active
FD	216-A-13	Air Sample Vacuum Pump Seal Drain (French Dr)	2 ft diam	11/55	-	Terminated
FD	216-A-14	Vacuum Cleaner Pit Drain (French Dr)	30 in. diam	11/55	1/73	Inactive
FD	216-A-15	Prop. Sampler Pit No. 5 Drain (French Dr)	2 ft diam	11/55	-	Active
FD	216-A-16	241-A Deentrainment Floor (Drain)	4 ft diam	1/56	3/69	Inactive
FD	216-A-17	Overflow from A-16	4 ft diam	1/56	3/69	Inactive
C	216-A-18	Startup Waste	6,400	11/55	12/55	Terminated
C	216-A-19	Startup Waste	625	11/55	12/55	Terminated
C	216-A-20	Startup Waste	625	11/55	12/55	Terminated
C	216-A-21	NH_3 Scrubber and Stack Drainage	960	10/57	6/65	Terminated
FD	216-A-22	203-A Con. and Floor Drain	6 ft diam	11/55	1/73	Inactive
FD	216-A-23A	241-A Fan House Drain	42 in. diam	1957	3/69	Inactive
FD	216-A-23B	Overflow from A-23A	42 in. diam	1957	3/69	Inactive
C	216-A-24	Tank Farm Condenser Effluent	28,000	5/58	1/66	Inactive
Pd	216-A-25	Cooling Water (Gable Mt. Pond)	71 acres	12/57	-	Active
FD	216-A-26A	Fan Control Room Drain	3 ft diam	3/59	7/65	Terminated
FD	216-A-26B	291 Fan House Drain	4 ft diam	3/59	6/73	Terminated
C	216-A-27	Lab, Scrubber and Stack Drain	2,000	6/65	7/70	Inactive
FD	216-A-28	203-A Floor Drainage	10 ft diam	12/58	11/67	Terminated
D	216-A-29	Cooling Water and Chemical Waste Ditch	39,000	11/55	-	Active
C	216-A-30	Steam Condensate	14,000	1/61	-	Active
C	216-A-31	Organic Waste	700	1/63	1/65	Inactive
C	216-A-32	E. Crane Maint. Plat. Floor Drain	560	1/59	-	Active
FD	216-A-33	291-A Stack Exhaust Fans Bearing Cooling Water	6 ft diam	11/55	7/64	Terminated
D	216-A-34	241-A Condensate Cooling Water	12,300	11/55	12/57	Terminated
FD	216-A-35	Vacuum Pump Seal Water	6 ft diam	12/63	1/66	Terminated
C	216-A-36A	Ammonia Scrubber Waste	1,100	9/65	3/66	Terminated
C	216-A-36B	Ammonia Scrubber Waste	5,500	3/66	9/72	Inactive
C	216-A-37	Steam Condensate	7,000	Not Used		Inactive
C	216-A-38	Process Condensate	7,800	Not Used		Inactive
C	216-A-39	241-AX-801 Building Drain	360	6/66	6/71	Inactive
T	216-A-40	244-AR Vault Cooling Water - Emergency Diversion	8,000	1/68	-	Inactive[(a)]
C	216-A-41	216-A-13 Stack Drainage	100	1/68	-	Active

(a) No diversion through CY-1973

TABLE II.1-C-3 (Continued)

Type of Construction	Number	Description	Bottom Area ft²	Use Dates From	To	Status
B PLANT						
C	216-B-1	Not Built				
D	216-B-2	Cooling Water and Chemical Sewer Ditch	24,570	4/45	-	Active
D	216-B-2-1 (-2E)	Cooling Water, Chemical Sewer Ditch	19,980	3/70	11/70	Terminated
D	216-B-2-2 (-2W)	Cooling Water, Chemical Sewer Ditch	14,200	3/70	5/70	Terminated
Pd	216-B-3	Cooling Water and Chemical Sewer Ditch	46 acres	4/45	-	Active
RW	216-B-4	292-B Floor Drainage	8 in. diam	4/45	12/49	Terminated
RW	216-B-5	224-B and 5-6 Waste	8 in. diam	4/45	10/47	Terminated
RW	216-B-6	222-B Waste	8 in. diam	4/45	12/49	Terminated
C	216-B-7A	224-B Waste and 5-6 Cell Drain	196	9/46	5/67	Terminated
C	216-B-7B	224-B Waste	196	10/46	5/67	Terminated
C	216-B-8	224-B, 5-6 and 2nd Cycle Waste	1,344	1945	1952	Terminated
C	216-B-9	5-6 and 2nd Cycle Waste	864	8/48	7/51	Terminated
C	216-B-10A	292-B Floor Drainage	196	12/49	-	Active 1967
C	216-B-10B	221-BC Decon. Waste	196	6/69	10/73	Inactive
RW	216-B-11A&B	242-B Condensate	4 ft diam	12/51	12/54	Terminated
C	216-B-12	U and B Plant Process Condensate	8,000	11/52	11/73	Inactive
FD	216-B-13	291-B Stack Drainage	4 ft diam	4/45	-	Active
C	216-B-14	U Plant Scavenged Waste	1,600	1/56	2/56	Terminated
C	216-B-15	U Plant Scavenged Waste	1,600	4/56	12/57	Terminated
C	216-B-16	U Plant Scavenged Waste	1,600	4/56	8/56	Terminated
C	216-B-17	Tank Farm Scavenged Waste	1,600	1/56	1/56	Terminated
C	216-B-18	U Plant Scavenged Waste	1,600	3/56	4/56	Terminated
C	216-B-19	U Plant and Tank Farm Scavenged Waste	1,600	2/57	10/57	Terminated
T	216-B-20	U Plant and Tank Farm Scavenged Waste	5,000	8/56	9/56	Terminated - Backfilled
T	216-B-21	U Plant and Tank Farm Scavenged Waste	5,000	9/56	10/56	Terminated - Backfilled
T	216-B-22	U Plant and Tank Farm Scavenged Waste	5,000	10/56	10/56	Terminated - Backfilled
T	216-B-23	U Plant and Tank Farm Scavenged Waste	5,000	10/56	10/56	Terminated - Backfilled
T	216-B-24	U Plant Scavenged Waste	5,000	10/56	11/56	Terminated - Backfilled
T	216-B-25	U Plant Scavenged Waste	5,000	11/56	12/56	Terminated - Backfilled
T	216-B-26	U Plant Scavenged Waste	5,000	12/56	2/57	Terminated - Backfilled
T	216-B-27	U Plant Scavenged Waste	5,000	2/57	4/57	Terminated - Backfilled
T	216-B-28	U Plant and Tank Farm Scavenged Waste	5,000	4/57	6/57	Terminated - Backfilled
T	216-B-29	U Plant Scavenged Waste	5,000	6/57	7/57	Terminated - Backfilled
T	216-B-30	U Plant and Tank Farm Scavenged Waste	5,000	7/57	7/57	Terminated - Backfilled
T	216-B-31	U Plant and Tank Farm Scavenged Waste	5,000	7/57	8/57	Terminated - Backfilled
T	216-B-32	U Plant and Tank Farm Scavenged Waste	5,000	8/57	9/57	Terminated - Backfilled
T	216-B-33	U Plant and Tank Farm Scavenged Waste	5,000	9/57	10/57	Terminated - Backfilled
T	216-B-34	U Plant and Tank Farm Scavenged Waste	5,000	10/57	10/57	Terminated - Backfilled
T	216-B-35	1st Cycle Supernatant - 221-B	2,520	2/54	3/54	Terminated - Backfilled
T	216-B-36	1st Cycle Supernatant - 221-B	2,520	3/54	4/54	Terminated - Backfilled
T	216-B-37	Evaporator Bottoms - 242-B	2,520	8/54	8/54	Terminated - Backfilled
T	216-B-38	1st Cycle Supernatant - 221-B	2,520	7/54	7/54	Terminated - Backfilled
T	216-B-39	1st Cycle Supernatant - 221-B	2,520	12/53	11/54	Terminated - Backfilled
T	216-B-40	1st Cycle Supernatant - 221-B	2,520	4/54	7/54	Terminated - Backfilled
T	216-B-41	1st Cycle Supernatant - 221-B	2,520	11/54	11/54	Terminated - Backfilled
T	216-B-42	U Plant Scavenged Waste	2,520	2/55	3/55	Terminated - Backfilled
C	216-B-43	U Plant Scavenged Waste	900	11/54	11/54	Terminated
C	216-B-44	U Plant Scavenged Waste	900	12/54	3/55	Terminated
C	216-B-45	U Plant Scavenged Waste	900	4/55	6/55	Terminated
C	216-B-46	U Plant Scavenged Waste	900	9/55	12/55	Terminated

TABLE II.1-C-3 (Continued)

Type of Construction	Number	Description	Bottom Area ft²	Use Dates From	Use Dates To	Status
C	216-B-47	U Plant Scavenged Waste	900	9/55	9/55	Terminated
C	216-B-48	U Plant Scavenged Waste	900	11/55	7/57	Terminated
C	216-B-49	U Plant Scavenged Waste	900	11/55	12/55	Terminated
C	216-B-50	ITS No. 1 Condensate	900	1/65	-	Active
FD	216-B-51	Pipe Line Drain BC Crib	5 ft diam	1/56	1/58	Terminated
T	216-B-52	Tank Farm Scavenged Waste	5,800	12/57	1/58	Terminated - Backfilled
T	216-B-53A	HLO Waste From 300 Area	600	10/65	11/65	Terminated - Backfilled
T	216-B-53B	HLO Waste From 300 Area	1,500	11/62	3/63	Terminated - Backfilled
T	216-B-54	HLO Waste From 300 Area	2,000	3/63	10/65	Terminated - Backfilled
C	216-B-55	B Plant Steam Condensate	7,500	9/67	-	Active
C	216-B-56	B Plant Organic Waste	700	Never Used		
C	216-B-57	ITS No. 2 Condensates	3,000	12/67	-	Active
T	216-B-58	300 Area Waste	2,000	11/65	6/67	Terminated - Backfilled
T	216-B-59	B Plant Cooling Water Diversion (Emergency)	8,000	12/67	-	Inactive[a]
C	216-B-60	Cell Drain Cleanout	8 ft diam	11/67	11/67	Terminated
C	216-B-61	ITS No. 1 Condensate	1,750	Not Used		Inactive
C	216-B-62	B Plant Process Condensate	5,000	11/73	-	Active
D	216-B-63	B Plant Chemical Sewer Ditch	5,000	3/70	-	Active
SEMIWORKS AND CRITICAL MASS LABORATORY						
C	216-C-1	201-C Process Condensate and Waste	184	1/53	6/57	Terminated
RW	216-C-2	291-C Stack and Filter Drain	12 in. diam	1/53	-	Active
C	216-C-3	271-C Chemical Waste	500	1/53	3/54	Terminated
C	216-C-4	276-C Organic Waste	200	7/55	5/65	Inactive
C	216-C-5	201-C High Salt Waste	200	3/55	6/55	Inactive
C	216-C-6	241-CX Waste Storage Cond.	200	9/55	9/64	Terminated
C	216-C-7	290-E Critical Lab Waste	400	5/61	-	Active
FD	216-C-8	271-CR Ion-Exchange Waste	6 ft diam	6/62	6/65	Terminated
Pd	216-C-9	C-Area Cooling Water Pond	80,000	6/53	-	Active (209-E only)
C	216-C-10	Strontium Semiworks Process Condensate	160	11/64	10/69	Inactive
200 NORTH AREAS						
Pd	216-N-1	212-N Basin Overflow Pond	50,000	9/44	6/52	Terminated - Backfilled
T	216-N-2	212-N Basin Cleanout Trench	500	3/47	4/47	Terminated - Backfilled
T	216-N-3	212-N Basin Cleanout Trench	500	5/52	6/52	Terminated - Backfilled
Pd	216-N-4	212-P Basin Overflow Pond	100,000	9/44	6/52	Terminated - Backfilled
T	216-N-5	212-R Basin Overflow Trench	1,200	5/52	6/52	Terminated - Backfilled
P	216-N-6	212-R Basin Overflow Pond	75,000	9/44	6/52	Terminated - Backfilled
T	216-N-7	212-R Basin Cleanout Trench	1,200	5/52	6/52	Terminated - Backfilled

C - crib D - ditch RW - reverse well
Pd - pond T - trench
Pt - pit FD - french drain
(a) No diversion through CY-1973

TABLE II.1-C-4

200 WEST AREA LIQUID WASTE DISPOSAL SITES
(Cribs, Ponds, Ditches, Trenches, Pits, French Drains, etc.)

Type of Construction	Number	Description	Bottom Area ft²	Use Dates From	Use Dates To	Status
REDOX PLANT, 222 Laboratory, 242-S						
C	216-S-1	D-2 Process Condensate	1,800	1/52	1/56	Terminated - Replaced by S-7
C	216-S-2	Overflow from S-1	1,800	1/52	1/56	Terminated - Replaced by S-7
C	216-S-3	241-S TK 101 and 104 Condensate	100	8/53	8/56	Terminated
FD	216-S-4	241-S TK 101 and 104 Condensate	30 in. diam	8/53	8/56	Terminated
C	216-S-5	Steam Condensate - Cooling Water	44,100	3/54	3/57	Terminated - Replaced by S-6
C	216-S-6	Steam Condensate - Cooling Water	44,100	11/54	7/72	Inactive
C	216-S-7	D-2 Process Condensate	5,000	1/56	7/65	Terminated
T	216-S-8	Startup Waste	6,000	11/51	2/52	Terminated - Backfilled
C	216-S-9	D-2 Process Condensate	9,000	7/65	1/69	Terminated
D	216-S-10	Ditch to S-11 Pond	13,500	2/54	-	Active
Pd	216-S-10	202-S Chemical Waste Pond	5 acres	5/54	7/72	Inactive
Pd	216-S-11	202-S Chemical Sewer Pond	1/5 acres	5/54	-	Active
T	216-S-12	291-S Stack Wash Water	1,800	7/54	7/54	Terminated - Backfilled
C	216-S-13	Organic Waste and 204-S Sump Waste	1,300	1/52	7/72	Inactive
T	216-S-14	Organic Startup Waste	800	12/51	1/52	Terminated - Backfilled
Pd	216-S-15	241-S TK 110 Condensate	175	12/51	10/52	Terminated - Backfilled
D	216-S-16	Process Cooline Water Ditch	6,800	9/56	7/72	Inactive
Pd	216-S-16	Process Cooling Water Pond #2	31 acres	9/56	-	Active
Pd	216-S-17	Process Cooling Water Pond #1	17 acres	3/52	4/54	Terminated - Covered
T	216-S-18	Steam Cleaning Pit	1,500	10/54	10/54	Terminated - Backfilled
Pd	216-S-19	222-S Cooling Water (Pond)	3.5 acres	2/52	-	Active
C	216-S-20	222-S Waste	3,600	3/52	5/73	Inactive
C	216-S-21	241-SX Condensate	2,500	11/54	12/70	Inactive
C	216-S-22	293-S Caustic Scrubber Waste	350	10/57	6/67	Terminated
C	216-S-23	Process Condensate (D-2)	3,600	1/69	7/72	Inactive
C	216-S-25	242-S Process and Steam Condensate	5,750	10/73	-	Active
T PLANT, 242-T EVAPORATOR						
D	216-T-1	Steam Heater Condensate - Ditch	5,475	11/44	-	Active
RW	216-T-2	222-T Lab Waste	3 in. diam	1/45	5/50	Terminated
RW	216-T-3	224-T and 5-6 Waste	8 in. diam	6/45	8/45	Terminated
D	216-T-4	Cooling Water Ditch	6,800	11/44	-	Active
Pd	216-T-4	Cooling Water Pond	2.5 acres	11/44	-	Active
T	216-T-5	2nd Cycle and 112-T Waste	500	5/55	5/55	Terminated
C	216-T-6	224-T and 5-6 Waste	1,260	8/46	6/51	Terminated
C	216-T-7	224, 5-6, and 2nd Cycle Waste	26,200	4/48	11/55	Terminated
C	216-T-8	222-T Lab Waste	1,260	5/50	9/51	Terminated
T	216-T-9	Equip. Decontamination Waste (Trench)	500	2/51	3/54	Terminated - Backfilled
T	216-T-10	Equip. Decontamination Waste (Trench)	500	6/51	3/54	Terminated - Backfilled
T	216-T-11	Equip. Decontamination Waste (Trench)	500	6/51	3/54	Terminated - Backfilled
Pt	216-T-12	Retention Basin Sludge (Pit)	150	11/54	11/54	Terminated - Backfilled
Pt	216-T-13	Equipment Decontamination Pit	400	6/54	6/64	Terminated - Backfilled
T	216-T-14	1st Cycle Supernate Waste (221-T)	2,200	1/54	1/54	Terminated - Backfilled
T	216-T-15	1st Cycle Supernate Waste (221-T)	2,400	1/54	2/54	Terminated - Backfilled
T	216-T-16	1st Cycle Supernate Waste (221-T)	2,400	2/54	2/54	Terminated - Backfilled
T	216-T-17	1st Cycle Supernate Waste (221-T)	2,400	2/54	6/54	Terminated
Pt	216-T-18	Scavenged Waste Supernatant (221-T)	100	11/53	11/53	Terminated - Backfilled
C	216-T-19	242-T Process & Steam Condensate	33,200	9/51		Active
Pt	216-T-20	155 TX Catch Tank Waste (Pit)	100	11/52	11/52	Terminated - Backfilled
T	216-T-21	1st Cycle Supernate Waste (221-T)	2,400	6/54	8/54	Terminated - Backfilled
T	216-T-22	1st Cycle Supernate Waste (221-T)	2,400	7/54	8/54	Terminated - Backfilled
T	216-T-23	1st Cycle Supernate Waste (221-T)	2,400	7/54	8/54	Terminated - Backfilled
T	216-T-24	1st Cycle Supernate Waste (221-T)	2,400	8/54	8/54	Terminated - Backfilled
T	216-T-25	242-T Evaporator Bottoms	1,800	9/54	9/54	Terminated - Backfilled
C	216-T-26	Scavenged Waste Supernatant (221-T)	900	8/55	11/56	Terminated - Backfilled
C	216-T-27	300 Area LOB Waste	900	9/65	11/65	Terminated
C	216-T-28	221-T Decontamination Waste	900	2/60	12/66	Terminated
FD	216-T-29	Sand Filter Drains	5,280	3/49	3/64	Inactive

TABLE II.1-C-4 (Continued)

Type of Construction	Number	Description	Bottom Area ft²	Use Dates From	Use Dates To	Status
	216-T-30	TK-154 Diversion Box Spill	14,400	7/53	7/53	Terminated - Covered
FD	216-T-31	241-TX French Drain	36 in. diam	10/54	2/62	Terminated - Replaced
C	216-T-32	224 T Waste	950	11/46	5/52	Terminated
C	216-T-33	2706-W Building Waste	150	1/63	2/63	Terminated
C	216-T-34	300 Area Waste	6,000	5/66	3/67	Terminated
C	216-T-35	300 Area Waste	4,500	3/67	12/67	Inactive
C	216-T-36	221-T, 221-U Miscellaneous Waste	1,600	6/67	12/68	Inactive
U PLANT						
C	216-U-1	224-U Waste	196	3/52	6/67	Terminated
C	216-U-2	Overflow from U-1	196	3/52	6/67	Terminated
FD	216-U-3	241-U TK 110 Condensate	72 in diam	5/54	8/55	Terminated
RW	216-U-4,4A, 4B	222-U Laboratory Waste	6, 36 and 36 in. diam	3/47	7/70	Terminated
T	216-U-5	Startup Waste - 221-U	400	3/52	3/52	Terminated - Backfilled
T	216-U-6	Startup Waste - 221-U	750	3/52	3/52	Terminated - Backfilled
FD	216-U-7	221-U Counting Box Floor Drainage	30 in. diam	3/52	6/57	Terminated
C	216-U-8	221-U, 224-U Process Condensate and 291-U Stack Drainage	8,000	6/52	4/60	Terminated - Replaced by U-12
D	216-U-9	Cooling Water and Chemical Waste Ditch (U-10 Pond Overflow)	19,800	3/52	4/54	Terminated - Backfilled
Pd	216-U-10	Cooling Water and Chemical Waste Pond	22 acres	7/44	--	Active
D	216-U-11	Overflow from U-10 Pond (Old Ditch)	9,000	11/44	7/55	Terminated - Backfilled
D	216-U-11	Overflow from U-10 Pond (New Ditch)	17,200	7/55	--	Active
C	216-U-12	224-U Process Condensate and 291-U-1 Stack Drainage	1,000	4/60	---	Active
T	216-U-13	241-UR Steam Cleaning Waste	8,000	3/52	3/56	Terminated - Backfilled
D	216-U-14	Laundry Ditch to U Pond	44,800	7/44		Active
Pt	216-U-15	Contaminated Solvent (Pit)	400	5/55	5/55	Terminated - Backfilled
Z PLANT						
D	216-Z-1	231-Z, 234-5 Cooling Water Ditch	17,000	12/44	3/59	Terminated - Backfilled
C	216-Z-1	D-6 Waste	196	6/49	4/69	Terminated
C	216-Z-1A	Overflow from Z-1, 2 and 3	26,000	6/49	3/59	Replaced by Z-12
		Reclamation Waste		6/64	4/69	Terminated
C	216-Z-2	D-6 Waste	196	6/49	6/52	Replaced by Z-3
		Reclamation Waste		6/52	5/66	Terminated
C	216-Z-3	D-6 Waste	350	6/52	3/59	Replaced by Z-12 - Terminated
Pt	216-Z-4	231-Z Lab Waste	100	6/45	6/45	Terminated - Backfilled
C	216-Z-5	231-Z Proc. Waste	1,120	6/45	2/47	Replaced by Z-7 Terminated
C	216-Z-6,6A	231-Z Proc. Waste	300	6/45	6/45	Terminated
C	216-Z-7	231-Z Lab Waste(a)	1,400	2/47	2/67	Terminated
FD	216-Z-8	Recuplex Waste	36 in. diam	7/55	4/62	Terminated
C	216-Z-9	Recuplex CAW Waste	1,800	7/55	6/62	Terminated
RW	216-Z-10	231-Z Waste	6 in. diam	2/45	6/45	Replaced by Z-5 Terminated
D	216-Z-11E	Cooling Water Ditch	10,680	6/49	5/71	Terminated - Backfilled
C	216-Z-12	D-6 Waste	6,000	3/59	5/73	Inactive
FD	216-Z-13	234-5 Tunnel Drain	36 in. diam	6/49		Active
FD	216-Z-14	Evaporator Cond. Water	36 in. diam	6/49		Active
FD	216-Z-15	Evaporator Cond. Water	36 in. daim	6/49		Active
C	216-Z-16	231-Z (BNW) Process waste	1,800	3/68		Active
T	216-Z-17	231-Z Ditch	3,000(b)	2/67	2/68	Terminated - Backfilled
C	216-Z-18	High Salt Waste	10,350(b)	4/69	5/73	Inactive
C	216-Z-19	234-5, 231-Z Cooling Water and Condensate	10,700	5/71		Active

(a) 2 cribs in parallel
(b) 5 cribs in parallel; two not used

C - crib, Pd - pond, Pt - pit, D - ditch, T - trench, FD - french drain, RW - reverse well

TABLE II.1-C-5

200 EAST AREA
DRY RADIOACTIVE WASTE BURIAL GROUNDS

Number	Description	Burial Ground Designation	Status
218-E-1	Dry Waste Burial Grounds	1	Inactive
218-E-2	Industrial Burial Grounds	2	Inactive
218-E-2A	Regulated Equipment Storage Site	2A	Inactive
218-E-4	Minor Construction Burial Grounds	4	Active
218-E-5	Industrial Burial Grounds	5	Inactive
218-E-5A	Industrial Burial Grounds	5A	Inactive
218-E-7	Vault (Behind 222-B)		Inactive
218-E-8	Construction Waste Burial Grounds		Inactive
218-E-9	Regulated Equipment Storage Site		Active
218-E-10	Industrial Waste Burial Grounds		Active
218-E-12A	Dry Waste Burial Grounds (North)	12	Active
218-E-12B	Dry Waste Burial Grounds (South)	12B	Active
218-E-13	Solid Waste Disposal Site (Contaminated Concrete)		Inactive
218-E-14	Failed Equipment Disposal Tunnel (Purex)	1	Inactive
218-E-15	Failed Equipment Disposal Tunnel (Purex)	2	Active

TABLE II.1-C-6

200 WEST AREA
DRY RADIOACTIVE WASTE BURIAL GROUNDS

Number	Description	Burial Ground Designation	Status
218-W-1	Dry Waste Burial Grounds	1	Inactive
218-W-1A	Industrial Waste Burial Grounds	1	Inactive
218-W-2	Dry Waste Burial Grounds	2	Inactive
218-W-2A	Industrial Burial Grounds	2	Active
218-W-3	Dry Waste Burial Grounds	3	Inactive
218-W-3A	Dry Waste Burial Grounds	3A	Active
218-W-4A	Dry Waste Burial Grounds	4A	Inactive
218-W-4B	Dry Waste Burial Grounds	4B	Active
218-W-4C	Dry Waste Burial Ground	4C	Active
218-W-7	Vault South of 222-S		Inactive
218-W-8	Vault South of 222-T		Inactive
218-W-9	Dry Waste Burial Grounds		Inactive
218-W-11	Regulated Equipment Storage Site		Active

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APPENDIX II.1-C, Part 3

Details of 200 East Area Facilities and Operations

II.1-C, Part 3 Details of 200 East Area Facilities and Operations

The flowchart of Figure II.1-C-3 depicts the transfer of waste generated in the Purex processing of N Reactor fuels. The fractionization of stored waste in B Plant requires the sluicing of tank farm sludges and the liquid waste transfers schematically depicted in Figure II.1-C-4.

Fuel Processing - Purex Plant

The irradiated fuel separation processes of Purex Plant yield waste streams which are routed to various processing and disposal sites. Figures II.1-C-5 and II.1-C-6 identify the waste streams produced by the Purex Plant and their destination, when Purex is both in operation and in standby status. Liquid waste lines emanating from the Purex Plant are shown in Figure II.1-C-7. They are described in Table II.1-C-7.

Waste Fractionization (B Plant) and Waste Encapsulation and Storage Facility (WESF)

The waste fractionization and encapsulation and storage activities of B Plant and WESF yield waste streams which are routed to various processing and disposal sites. Figures II.1-C-8 and II.1-C-9 identify the waste streams produced in B Plant and their destination, when B Plant is both in operation and in standby status. Figure II.1-C-10 identifies waste streams produced in the waste encapsulation storage facility.

Liquid waste lines emanating from B Plant and the WESF are shown in Figure II.1-C-11. They are described in Table II.1-C-8. Lines used in the transfer of stored waste for fractionization are shown in Figures II.1-C-12 and II.1-C-13, and are described in Tables II.1-C-9 and II.1-C-10. The 244-AR vault has an active role in waste processing and transfer operations. Input/output diagrams for vault activities are shown in Figures II.1-C-14, II.1-C-15, and II.1-C-16 for processing current acid wastes and acidified sludge, and standby.

Boiling Waste Storage Facility Effluents

Liquid waste lines used to dispose of process condensate and condenser cooling water are shown in Figure II.1-C-17. They are described in Table II.1-C-11.

In-Tank Solidification - 200 East Area

Inter and intratank farm lines used for ITS processes in B, BX and BY tank farms are shown in Figures II.1-C-18 and II.1-C-19. The lines are described in Tables II.1-C-12 and II.1-C-13.

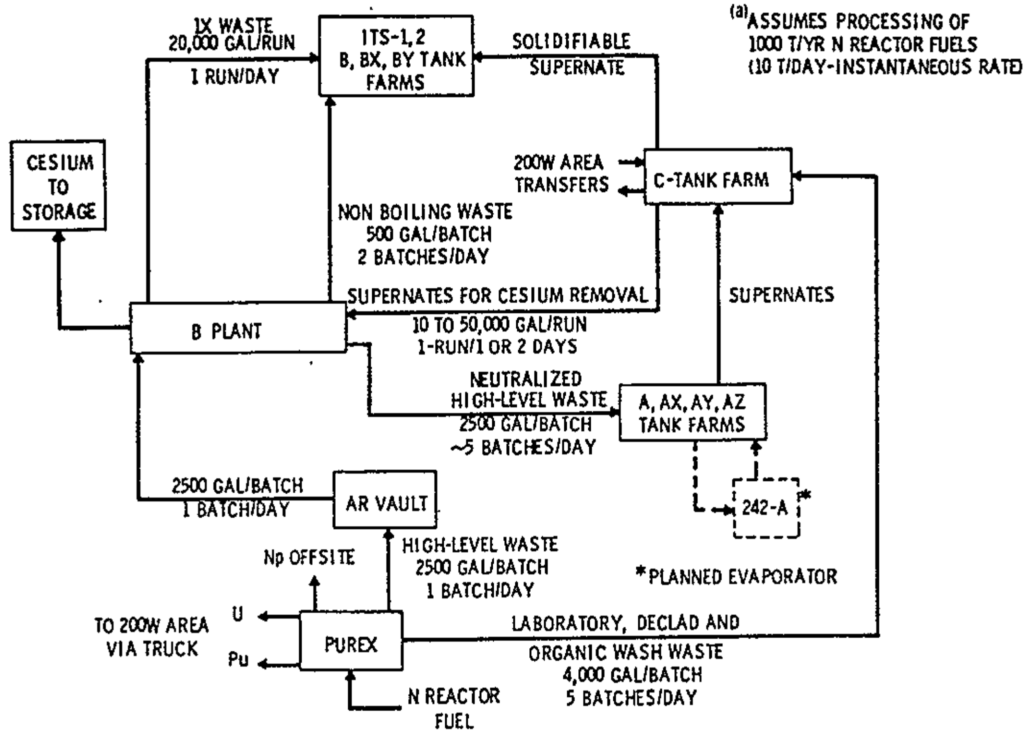

FIGURE II.1-C-3 TYPICAL PROCESS SOLUTION TRANSFERS 200 EAST AREA - N FUELS PROCESSING[a]

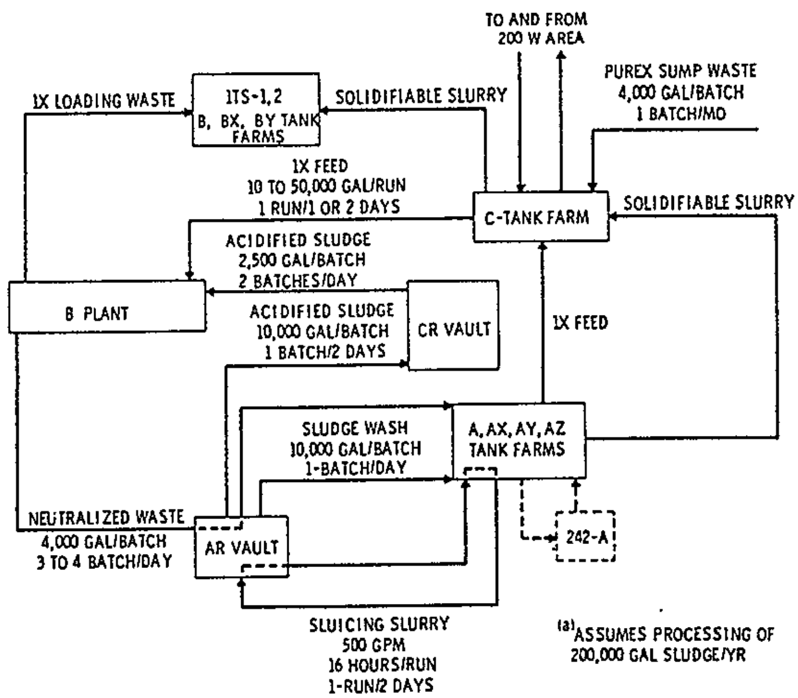

FIGURE II.1-C-4 TYPICAL PROCESS SOLUTION TRANSFERS 200 EAST AREA - PAS PROCESSING[a]

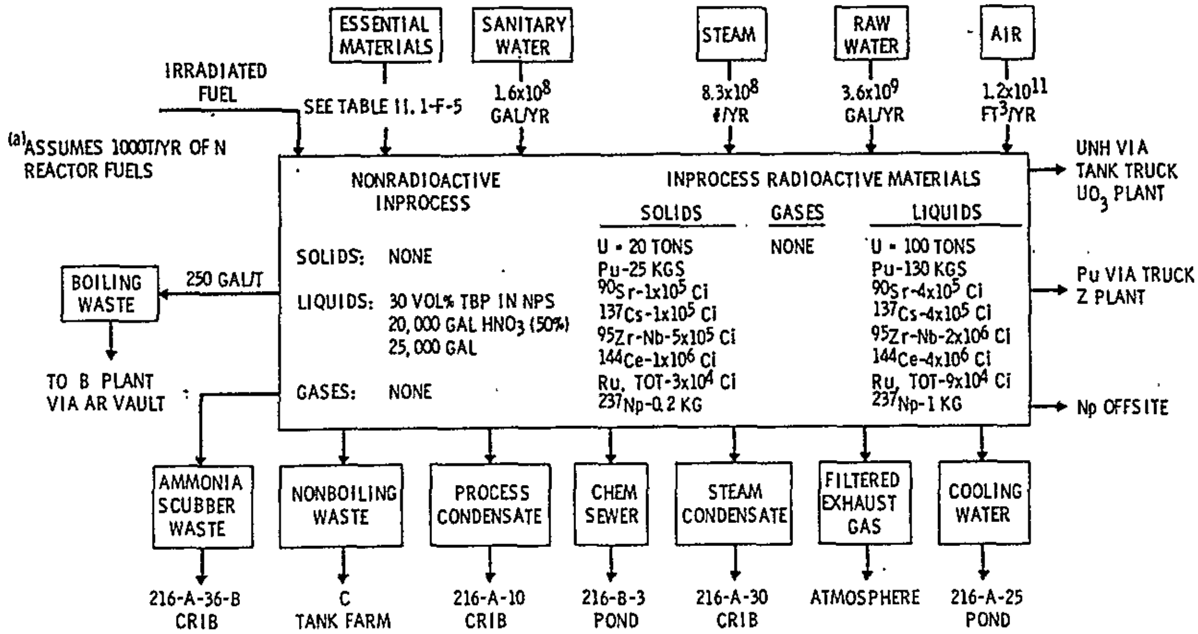

FIGURE II.1-C-5 PUREX PLANT INPUT-OUTPUT DIAGRAM (OPERATING N FUELS)[a]

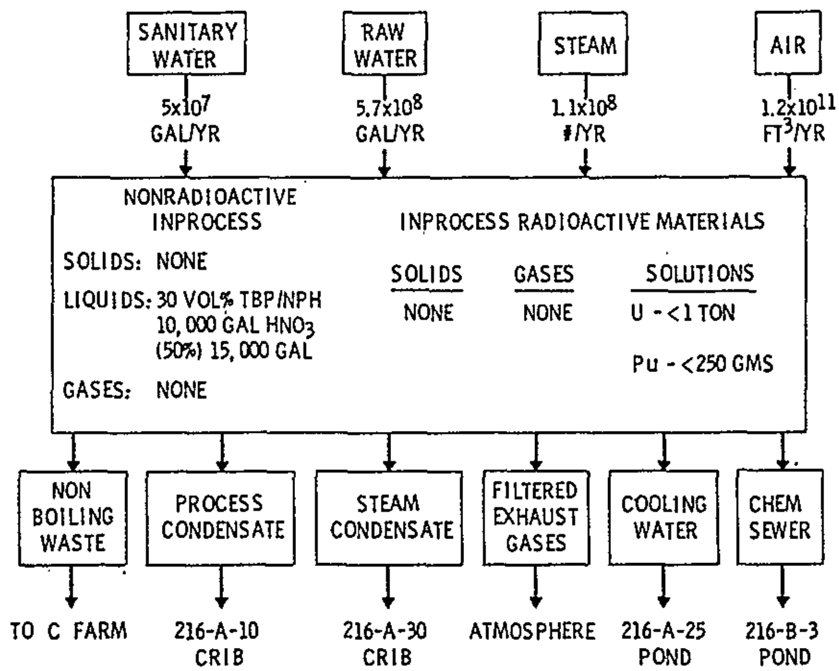

FIGURE II.1-C-6 PUREX PLANT INPUT-OUTPUT DIAGRAM (STANDBY)

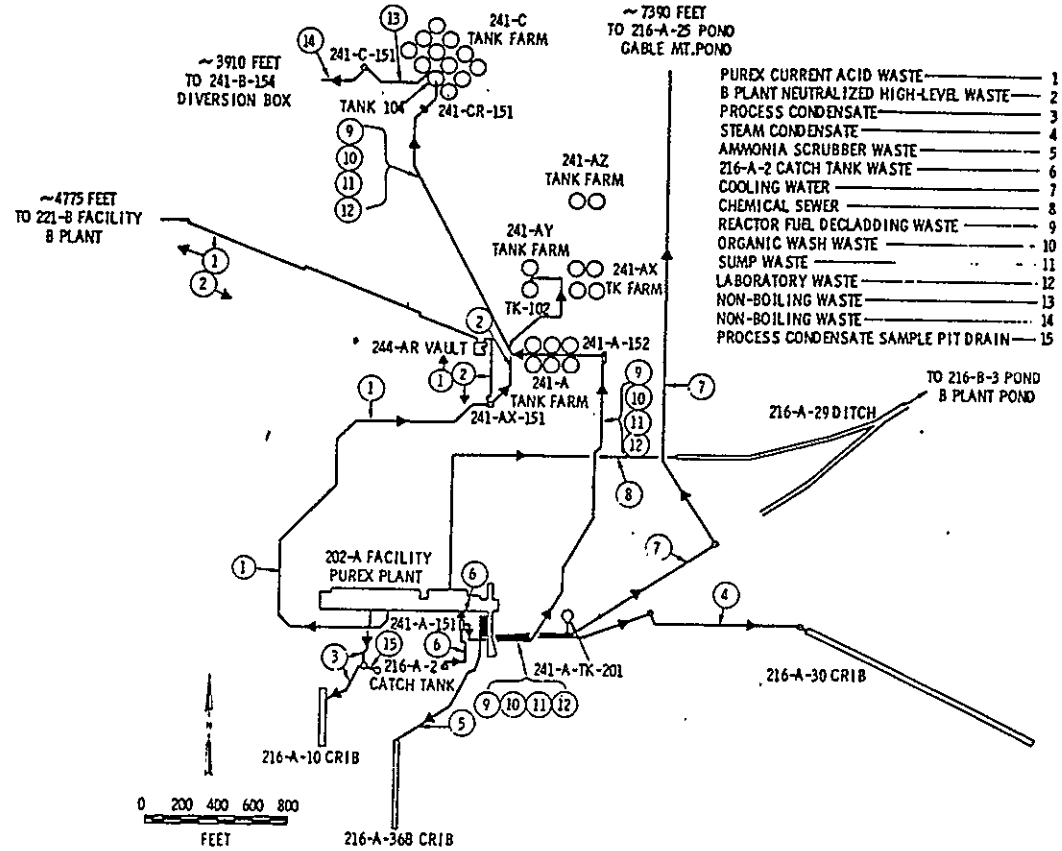

FIGURE II.1-C-7 202-A FACILITY PUREX PLANT ACTIVE WASTE TRANSFER LINES

TABLE II.1-C-7

PUREX PLANT ACTIVE WASTE TRANSFER LINES

	Function	Description	Cathodic Protection	Secondary Containment	Burial Depth (feet)	Age (years)
1.	Current Acid Waste to B Plant via 244-AR Vault	3 in., Stainless Steel (schedule 10)	Not Required	Concrete	8 to 20	7 to 23
2.	High-Level Waste B Plant to AY and AZ Tanks via 244-AR Vault	3 in., Stainless Steel (schedule 10)	Not Required	Concrete; with Line #1	5 to 20	0 to 23
3.	Process Condensate to 216-A-10 Crib	8 in., Stainless Steel (schedule 5)	Yes	No	25	11
4.	Steam Condensate to 216-A-30 Crib	16 in., Steel (schedule 40)	Not Required; Coated and Wrapped	No	5 to 25	5 to 19
5.	NH_3 Scrubber Waste to 216-A-368 Crib	6 in., Stainless Steel to	Yes	No	11 to 21	9
6.	216-A-2 Catch Tank into Purex	4 in., Stainless Steel (schedule 10)	Yes	No	4 to 20	6 to 19
7.	Cooling Water to 216-A-25 (Gable Mt.) Pond	30 in., Steel (Schedule 30); 30 in. extra-strength vitreous clay; 30 to 42 in. 14 gauge corrugated metal	Not Required	No	2 to 13	16
8.	Chemical Sewer to 216-B-3 Pond	12 in., Vitreous Clay	Not Required	Concrete; Partial	6 to 13	19
9.	Decladding Waste to C Farm Tank 104	3 in., Stainless Steel (schedules 10 and 40)	Partial	Concrete; Partial	9 to 19	7 to 20
10.	Organic Wash Waste to C Farm Tank 104	3 in., Stainless Steel (schedules 10 and 40)	Partial	Concrete; Partial	9 to 19	7 to 20
11.	Sump Waste to C Farm Tank 104	3 in., Stainless Steel (schedules 10 and 40)	Partial	Concrete; Partial	9 to 19	7 to 20
12.	Lab. Waste to C Farm Tank 104	3 in., Stainless Steel (schedules 10 and 40)	Partial	Concrete; Partial	9 to 19	7 to 20
13.	C Farm Tank 104 to 241-C-151 Diversion Box (nonboiling waste)	3 in., Stainless Steel (schedule 40)	Yes	No	2 to 12	3
14.	Nonboiling Waste, 241-C-151 to 241-B-154 Diversion Boxes	3 in., 11 gauge 18-8 Columbian Stainless Steel	Yes	No	5 to 10	27
15.	Process Condensate Sample Pit to 216-A-5	4 in., Stainless Steel (schedule 40)	Yes	No	34	20

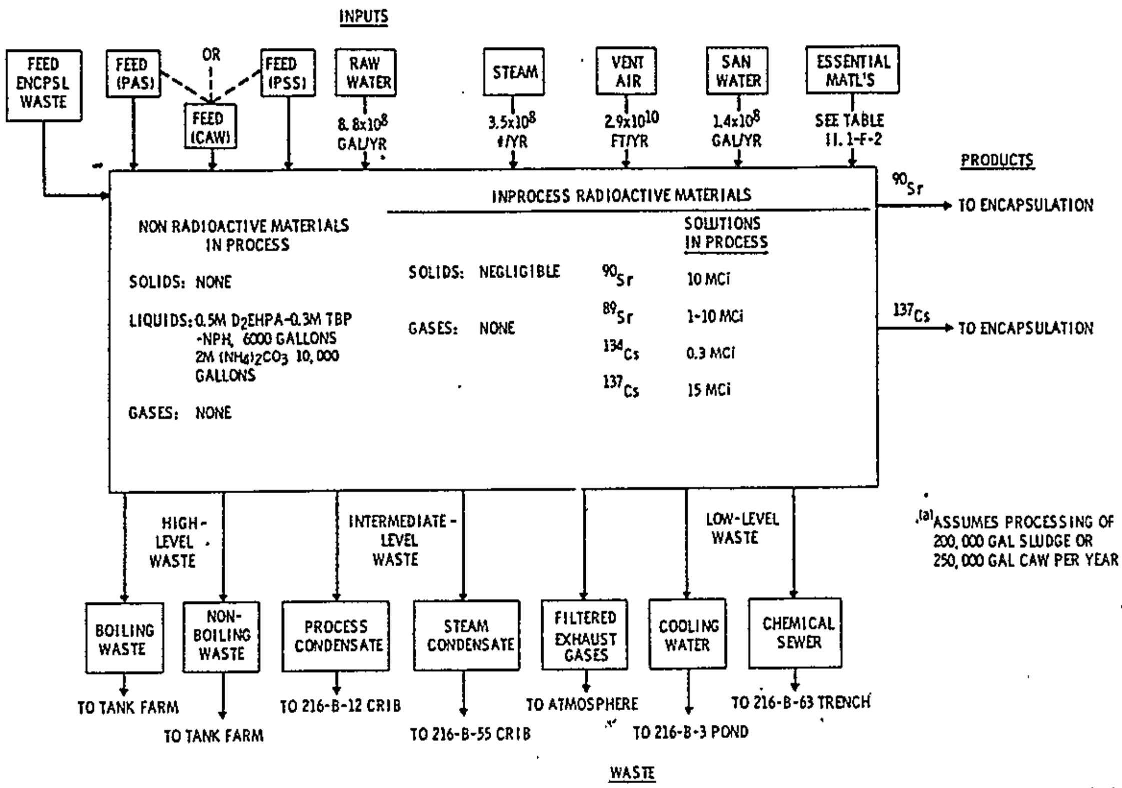

FIGURE II.1-C-8 WASTE FRACTIONIZATION - B PLANT PROCESS INPUT-OUTPUT DIAGRAM (OPERATING)[a]

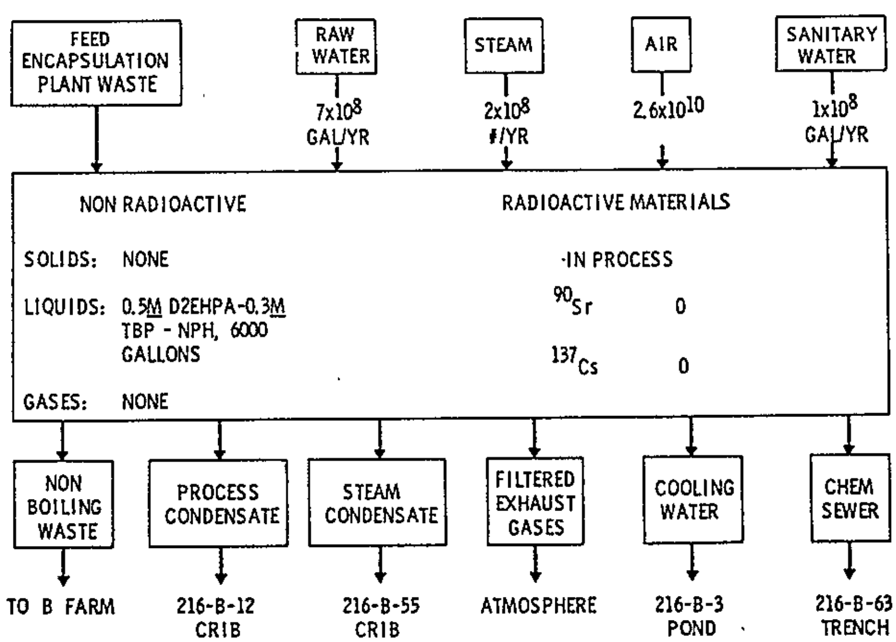

FIGURE II.1-C-9 WASTE FRACTIONIZATION - B PLANT PROCESS INPUT-OUTPUT DIAGRAM (STANDBY)

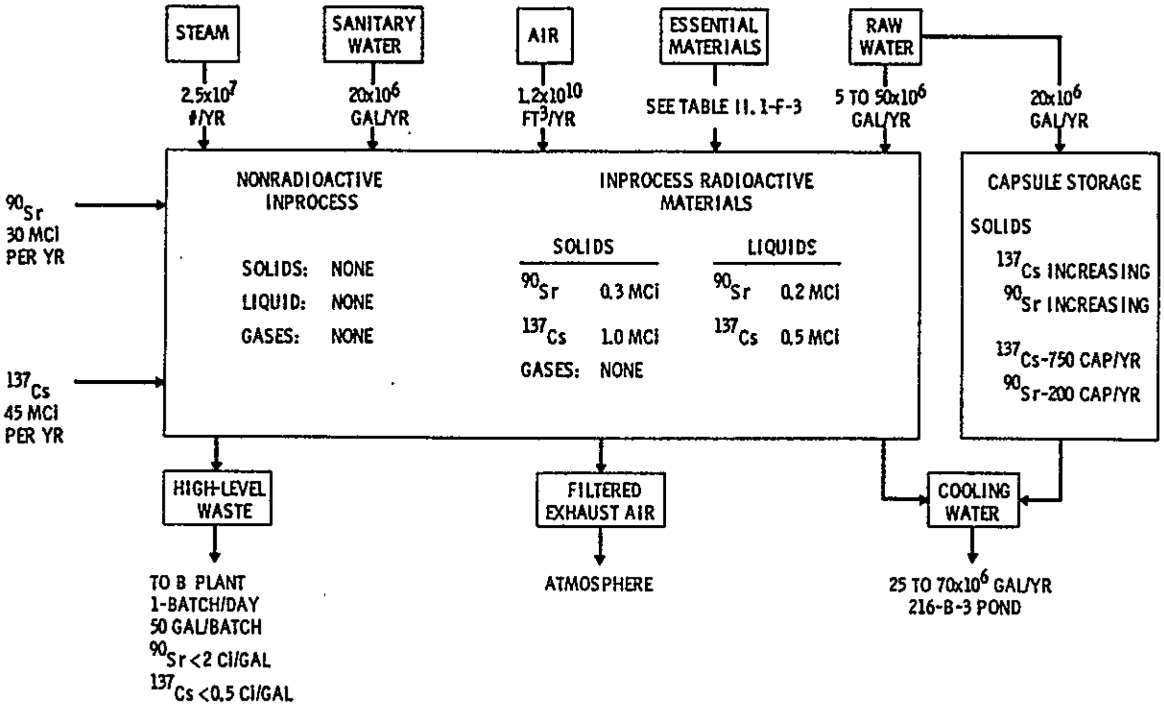

FIGURE II.1-C-10 225-B ENCAPSULATION INPUT-OUTPUT DIAGRAM

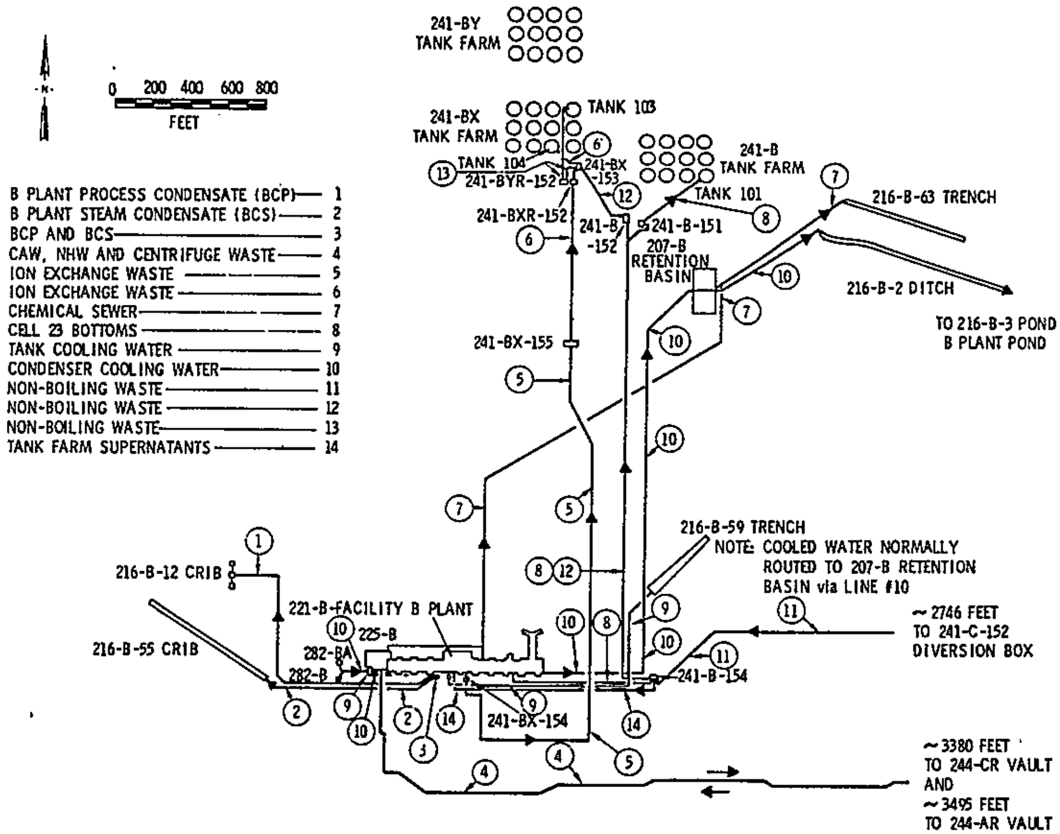

FIGURE II.1-C-11 221-B AND 225-B ENCAPSULATION ACTIVE WASTE TRANSFER LINES

TABLE II.1-C-8

B PLANT ACTIVE WASTE TRANSFER LINES

	Function	Description	Cathodic Protection	Secondary Containment	Buried Depth (feet)	Age (years)
1.	Process Condensate Sample Tank to 216-B-12 Crib	4 in., Steel (schedule 40), and 4 in., Fiberglass	Not Required, coated and wrapped	No	3 to 13	5 to 8
2.	Steam Condensate Sample Tank to 216-B-55 Crib	6 in., Steel (schedule 40)	Not Required, coated and wrapped	No	4 to 9	8
3.	5 Lines: B Plant Condensates to Sample Tanks of #1 and #2	3 in., SS (sch. 40)-2 4 in., SS (sch. 40)-2 3 in., SS (sch. 10)-2	Yes	No	5	8
4.	2 Lines: High-level Waste to and from 244-AR Vault (Purex Table #1 and #2)	3 in., Stainless Steel (schedule 10)	Not Required	Concrete	4 to 20	0 to 23
5.	Ion Exchange Waste: 241-BX-154 to 241-BX-155 Diversion Boxes	3.5 in., 11 gauge 18-8 Columbian Stainless Steel	Not Required	Concrete	8 to 12	26
6.	Ion Exchange Waste: 241-BX-155 to 241-BX-153 Div. Box, to BX Farm Tank 104	3.5 in., 11 gauge 18-8 Columbian Stainless Steel	Yes	No[(a)]	10 to 21	27
7.	Chemical Sewer to 216-B-63 Trench	6 to 15 in. Vitreous Clay; Acid Proof Joints	Not Required	No	5.5 to 15.5	1 to 25
8.	Cell 23 Bottoms to B Farm Tank 101 via 241-B-154 and 241-B-151 Diversion Boxes	3.5 in., 11 gauge 18-8 Columbian Stainless Steel	Yes	No[(a)]	5 to 22	24 to 27
9.	High-risk Cooling Water to 216-B-3 Pond via 207-B Retention Basin	6 in., Steel (sch. 40); 8 to 12 in., Steel (sch. 20); 14 in., Steel (sch. 10); 15 in., Extra Strength Vitrified Clay	Not Required, Coated and Wrapped	No	4 to 14	7
10.	Low-risk Cooling Water to 216-B-3 Pond via 207-B Retention Basin	24 in., Cast Iron; 24 and 30 in., Vitreous Clay	Not Required	No	4 to 18	24
11.	2 Lines; 241-C-151 to 241-B-154 Diversion Boxes (Purex Table #14)	3 in., 11 gauge 18-8 Columbian Stainless Steel	Yes	No	5 to 10	27
12.	241-B-154 to 241-B-152 to 241-BX-153 Diversion Boxes	3.5 in., 11 gauge 18-8 Columbian Stainless Steel	Yes	No	10 to 14	27
13.	241-BX-153 and 241-BYR-152 Diversion Boxes to BX Farm Tank 103	3 in., Steel (sch. 40); 6 in., Steel (sch. 80)	Not Required; coated and wrapped	Concrete, Partial	3 to 10	7 to 22
14.	Tank Farm Supernatant from 241-B-154 Diversion Box	3.5 in., 11 gauge 18-8 Columbian Stainless Steel	Yes	No	5 to 12	24

(a) To be replaced with encased line.

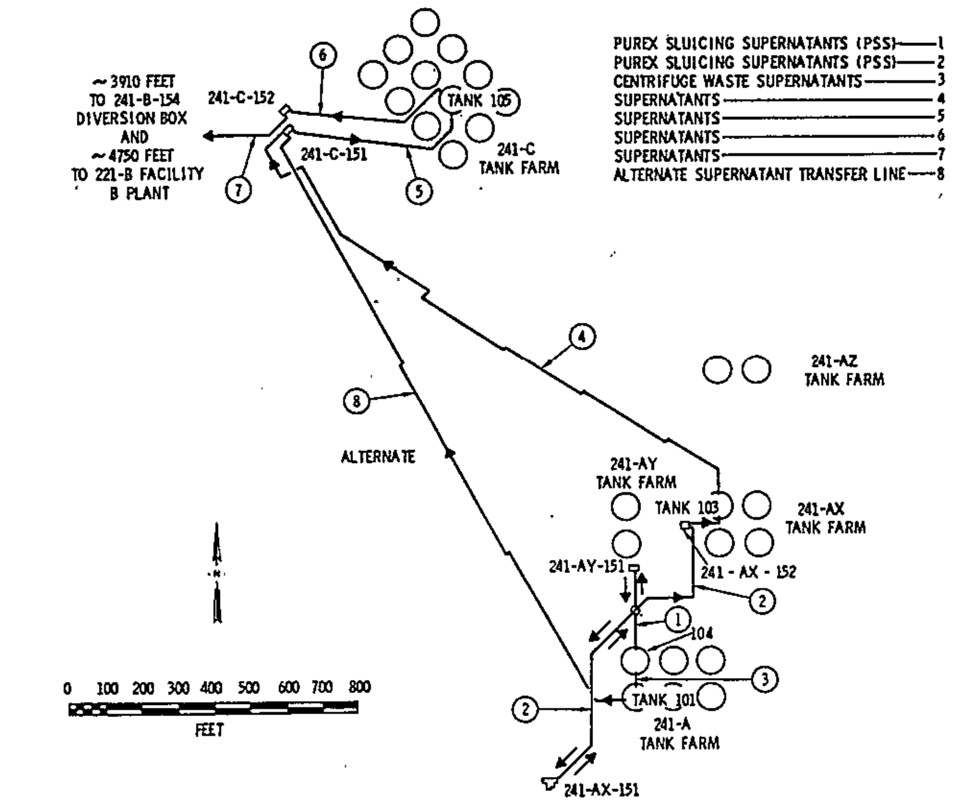

FIGURE II.1-C-12 244-AR VAULT ACTIVE WASTE TRANSFER LINES FOR TANK FARM SUPERNATANTS

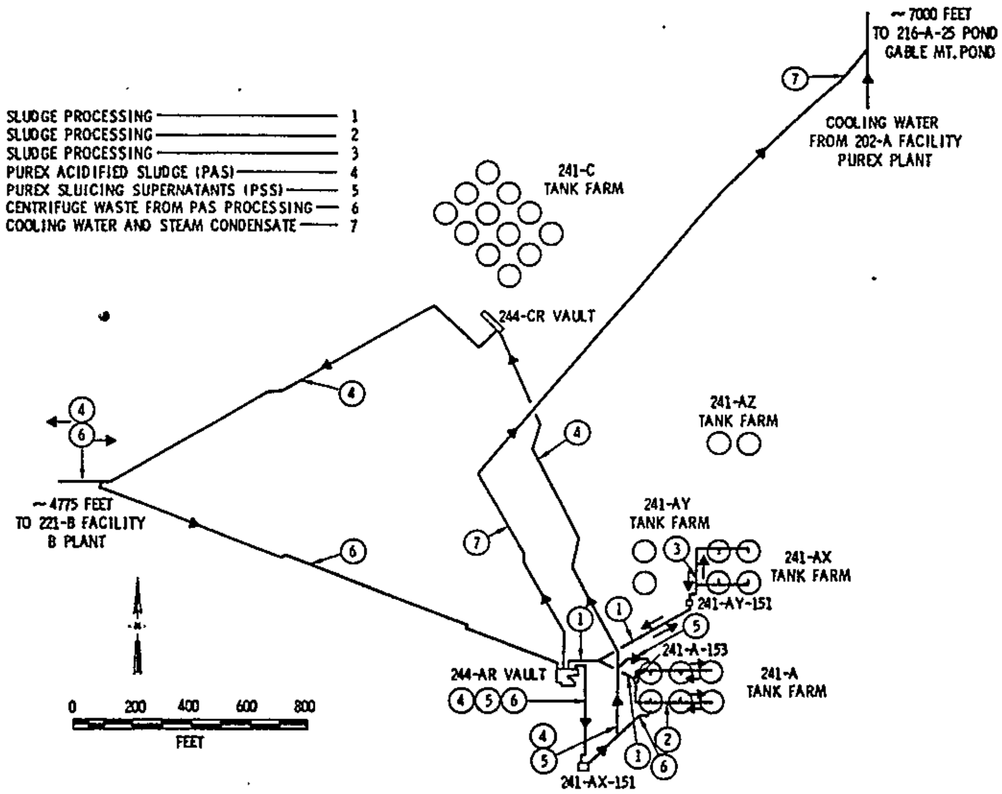

FIGURE II.1-C-13 244-AR VAULT ACTIVE WASTE TRANSFER LINES FOR SLUDGE SLUICING

TABLE II.1-C-9

TANK FARM ACTIVE TRANSFER LINES FOR SUPERNATANT

	Function	Description	Cathodic Protection	Secondary Containment	Buried Depth (feet)	Age (years)
1.	Sluicing Supernatant A Farm Tank 104 to 241-AY-151 Diversion Box	3 in., Steel (schedule 40)	Not Required; coated and wrapped	No	3 to 9	4
2.	Sluicing Sup., 241-AY-151 to AX Farm Tank 103	3 and 4 in., Steel (schedule 10)	Not Required	Concrete; Galvanized Corrugated 16 ga. metal	5 to 21	10 to 11
3.	Centrifuge Sup., A Farm Tank 101 to Tank 104	4 in., Steel (schedule 80)	Not Required; coated and wrapped	No	3 to 8	20
4.	AX Farm Tank 103 to 241-C-151 Diversion Box	3 in., Steel (schedule 40)	Yes	No[a]	5 to 11	6
5.	241-C-151 Diversion Box to C Farm Tank 105	3 in., 18-8 Columbian Stainless Steel; 3 in., SS (sch. 10)	Yes	No	2 to 13	3
6.	C Farm Tank 105 to 241-C-152 Diversion Box	3 in., Stainless Steel (schedule 40)	Yes	No	2 to 13	3
7.	241-C-152 Diversion Box to B Plant Via 241-B-154 Diversion Box	3 in., 11 gauge 18-8 Columbian Stainless Steel	Yes	No	5 to 10	27
8.	Alternate Line; A Farm Tank 101 to C Farm Tank 105 via 241-C-151 Diversion Box	2 in., Steel (schedule 40)	Yes	No[a]	3 to 7.5	10

(a) To be replaced with encased lines

TABLE II.1-C-10

244-AR VAULT ACTIVE TRANSFER LINES FOR SLUDGE

	Function	Description	Cathodic Protection	Secondary Containment	Buried Depth (feet)	Age (years)
1.	4 Lines: A Farm via 241-A-153 diversion box, and AX Farm via 241-AY-152 sluice transfer box	6 in., Steel (schedule 40)	Yes	No	4 to 14	7
2.	A Farm, from Tanks 102, 103, 106 to #1 Above	6 in., Steel (schedule 40)	Not Required; coated and wrapped	No	3 to 8.5	7
3.	AX Farm, from Tanks 101, 103, 104 to #1 Above	6 in., Steel (schedule 40)	Not Required; coated and wrapped	Concrete	2 to 3.5	<1
4.	Acidified Sludge to B Plant via 241-AX-151 Diverter Station and 244-CR Vault	3 and 4 in., Stainless (schedule 10); 2, 3 and 3.5 in., SS (schedule 40)	Partial	Concrete; Partial	4 to 19	7 to 23
5.	Sluicing Supernatant to A Farm Tank 104	3 and 4 in., Stainless (schedule 10)	Yes	Concrete; Partial[a]	5 to 17	7 to 10
6	Centrifuge Waste, B Plant to A Farm Tank 101 via Vault and 241-AX-151 Diversion Box	3 to 4 in., Stainless (schedule 10) 3.5 in. Stainless	Partial	Concrete; Partial	4 to 20	0 to 23
7.	Cooling Water and Steam Condensate to 216-A-25 (Gable Mt.) Pond	2, 3 and 6 in. Steel; 12 in., Concrete	Not Required; coated and wrapped	No	5 to 16	7

(a) Direct burial portion of line will be replaced with encased line

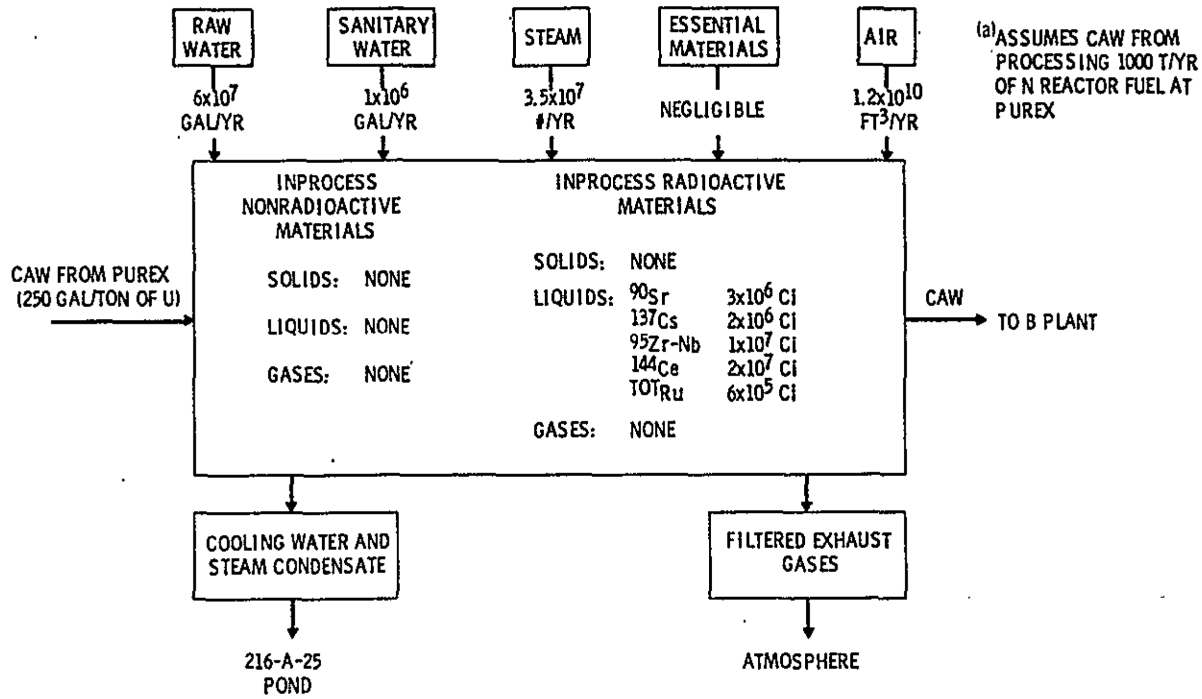

FIGURE II.1-C-14 244-AR VAULT INPUT-OUTPUT DIAGRAM - CAW PROCESSING[a]

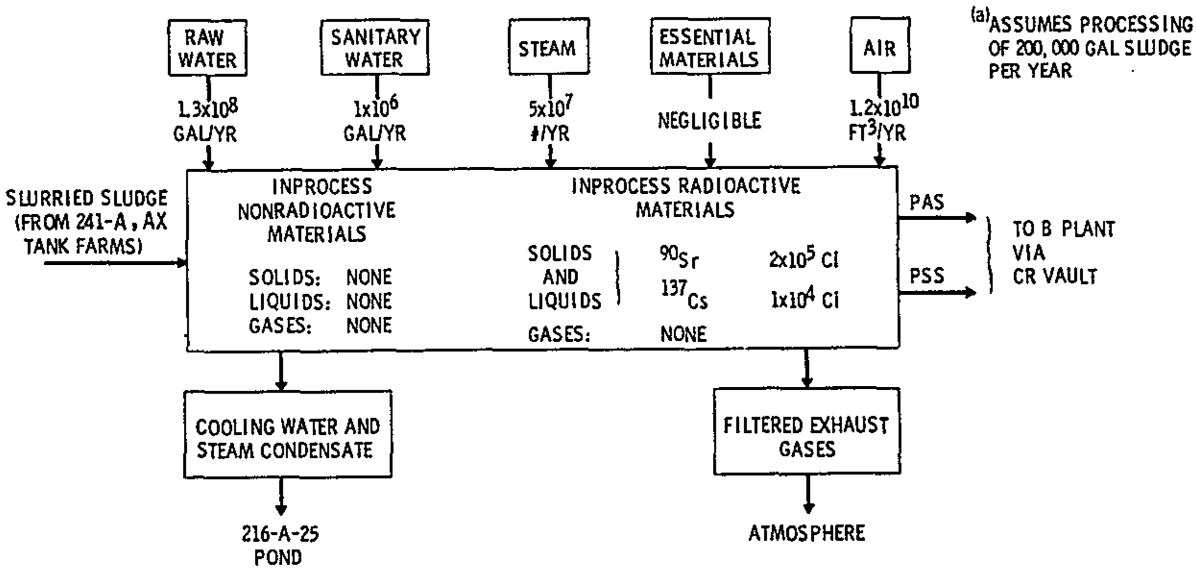

FIGURE II.1-C-15 244-AR VAULT INPUT-OUTPUT DIAGRAM - PAS PROCESSING[a]

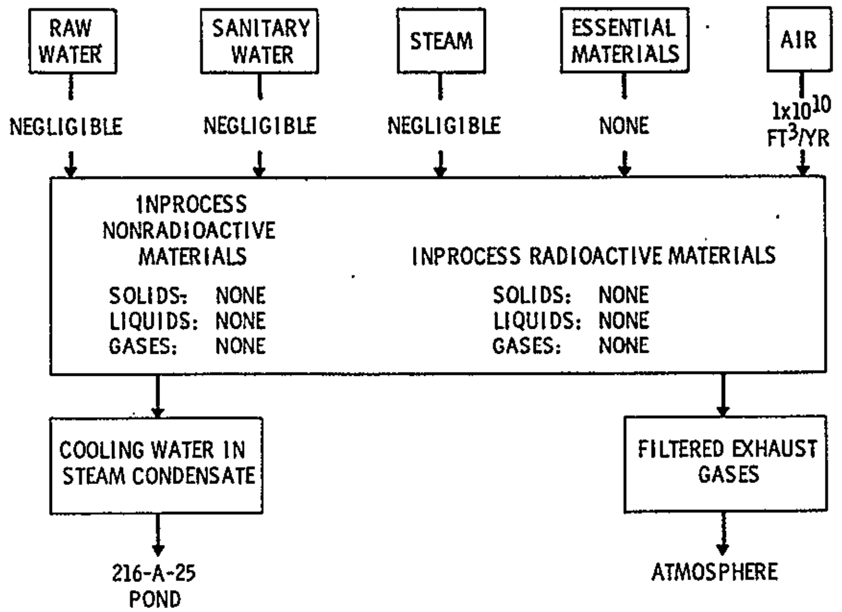

FIGURE II.1-C-16 244-AR VAULT INPUT-OUTPUT DIAGRAM (STANDBY)

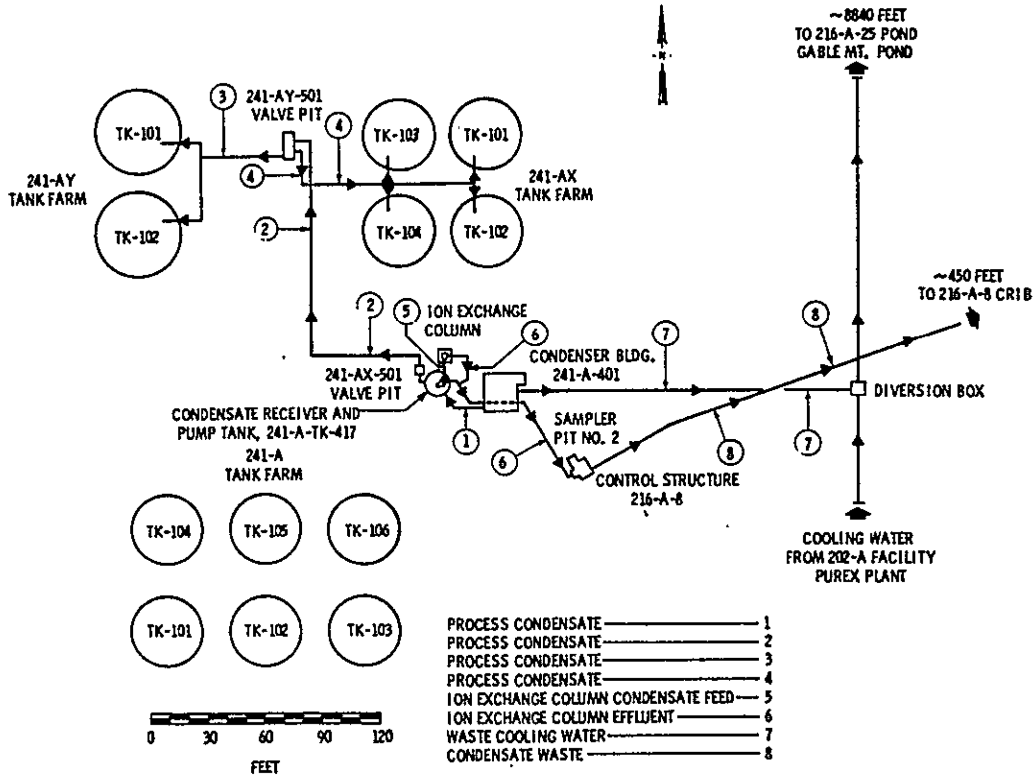

FIGURE II.1-C-17 A, AX, AND AY TANK FARMS ACTIVE WASTE TRANSFER LINES FOR PROCESS CONDENSATES AND COOLING WATER

TABLE II.1-C-11

A, AX AND AY TANK FARMS: ACTIVE WASTE TRANSFER LINES FOR PROCESS CONDENSATES AND COOLING WATER

	Function	Description	Cathodic Protection	Secondary Containment	Buried Depth (feet)	Age (years)
1.	Proc. Cond. from Condensers to Receiver and Pump Tank 241-A-TK-417	6 in., Steel (schedule 80)	Not required; coated and wrapped	no	14 to 16	16
2.	241-A-TK-417 to 241-AY-501 Valve Pit	2 and 3 in., Steel (schedule 40)	Not required; coated and wrapped	No	6 to 12	5 to 11
3.	241-AY-501 to AY Farm Tanks 101 and 102	2 in., Steel (schedule 40)	Not required; coated and wrapped	No	10 to 12	5
4.	241-AY-501 to AX Farm Tanks 101, 102, 103 and 104	2 and 4 in., SS (schedule 10)	Not required	Concrete	10 to 20	5 to 11
5.	241-A-TK-417 to Ion Exchange Column	2 in., Steel (schedule 40)	Not required; coated and wrapped	No	3 to 9	4
6.	241-A-TK-417 Overflow and Ion Exchange Column to Sampler Pit #2	2 in., Steel (sch. 40); 6 in. Steel (sch. 30)	Not required; coated and wrapped	No	3 to 16	4 to 15
7.	Cooling Water: Condensers to 216-A-25 (Gable Mt.) Pond	21 in., 16 gauge galvanized Corrugated (asphalt coated) metal	Not required; coated	Concrete under roadways	11 to 37	16
8.	Condensate; Sampler Pit #2 to 216-A-8 Crib	16 in., Steel (schedule 20)	Not required; coated and wrapped	Concrete under road	4 to 7	18

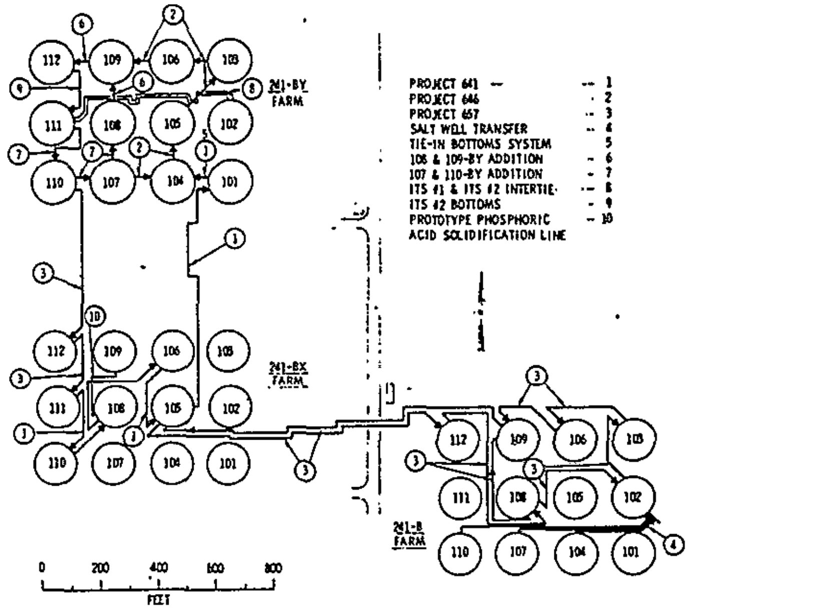

FIGURE II.1-C-18 ITS NO. 1 AND ITS NO. 2 ACTIVE INTERFARM WASTE TRANSFER LINES

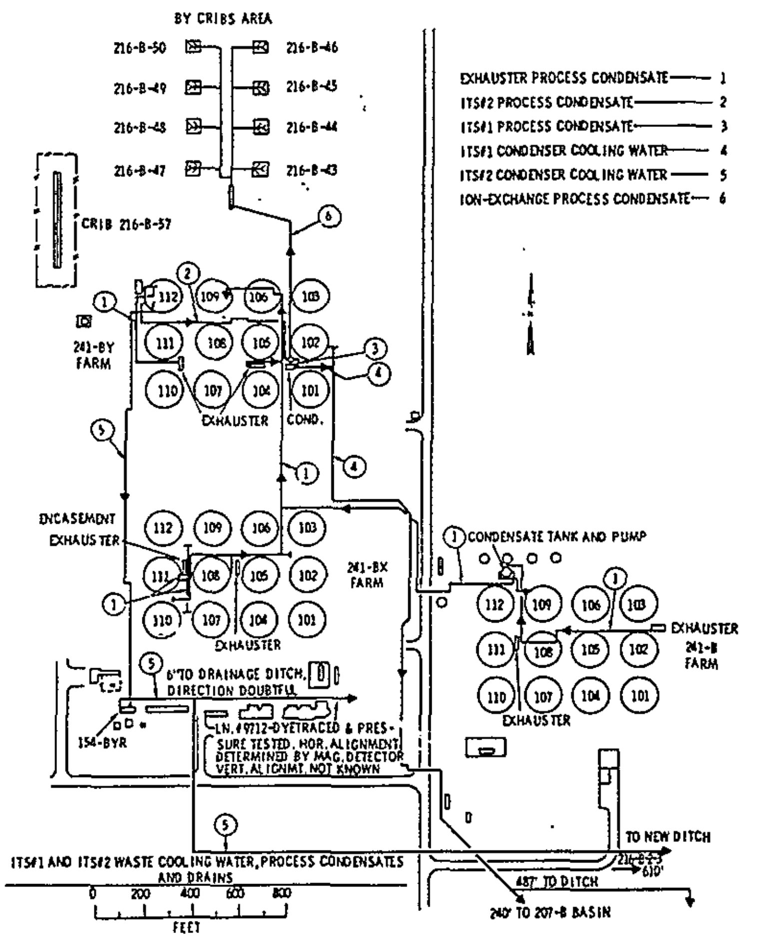

FIGURE II.1-C-19 ITS NO. 1 AND ITS NO. 2 ACTIVE WASTE TRANSFER LINES FOR PROCESS CONDENSATES AND COOLING WATER

TABLE II.1-C-12

ITS NO. 1 AND 2 ACTIVE INTERFARM WASTE TRANSFER LINES

	Function	Description	Cathodic Protection	Secondary Containment	Buried Depth (feet)	(years)
1.	BX Farm Tank 105 to BY Farm Tank 101 BX Farm Tanks 105 to 106, 110 to 111, BY Farm Tanks 101 to 104 (Project 641)	3 in., Steel (schedule 40)	Not required; insulated	No	3 to 9	5
2.	BY Farm Tanks 107 to 104 to 105 to 103 to 106 to 109 (Project 646)	3 in., Steel (schedule 40)	Not required; insulated	No	3 to 9	3
3.	B Farm Tank 109 to BX Farm Tank 105; BX Farm Tank 112 to BY Farm Tank 110; B Farm Tanks 112 to 108 to 102 to 103 to 106 to 109 to 108; BX Farm Tanks 110 to 108 to 106, 112 to 111 (Project 657)	3 in., Steel (schedule 40)	Not required; insulated	No	3 to 8	2
4.	Salt Well Liquid in B Farm; to Tank 102 from Tanks 101, 104, 107, 110	2 in., Steel (schedule 40)	Not required; insulated	No	4 to 6	1
5.	BY Farm Tanks 102 to 105; B Farm Tanks 101 to 105	3 in., Steel (schedule 40)	Not required; insulated	No	2 to 5	1
6.	BY Farm Tanks 108 to 109 to 112	3 in., Steel (schedule 40)	Not required; insulated	No	1.5 to 3	6
7.	BY Farm Tanks 111 to 110 to 107 to 108	3 in., Steel (schedule 40)	Not required; insulated	No	1 to 3.5	5
8.	BY Farm Tanks 102 to 111	3 in., Steel (schedule 40)	Not required; insulated	No	1 to 2	1
9.	BY Farm Tanks 112 to 111	1.5 in., Steel (schedule 40)	Not required; insulated	No	4	8
10.	BX Farm Tanks 108 to 109 (Phosphoric Acid Solidification Process Prototype)	2 in., Steel (schedule 40)	Not required; insulated	No	3	1

TABLE II.1-C-13

ITS NO. 1 AND 2 ACTIVE WASTE TRANSFER LINES FOR PROCESS CONDENSATES AND COOLING WATER

	Function	Description	Cathodic Protection	Secondary Containment	Buried Depth (feet)	Age (years)
1.	Condensate from Tank Exhausters to BY Farm Tank 109; B Farm-2 Exhausters BX Farm-2 Exhausters BY Farm-1 Exhauster	1.5 and 2 in., Steel (schedule 40)	Not Required; coated and wrapped	No	2 to 6	2 to 7
2.	Condensate from one BY Farm Exhauster and ITS #2 to Ion Exchange Unit	1 and 2 in., Steel (schedule 40)	Not Required; coated and wrapped	No	3 to 7	1 to 9
3.	Condensate from ITS #1 to Ion Exchange Unit	2 in., Steel (schedule 40)	Not Required; insulated	No	Above Ground (5 feet)	6
4.	ITS #1 Condenser Cooling to 216-B-3 Pond via 207-B Retention Basin	4 in., Steel (schedule 40)	Not Required; coated and wrapped	No	3 to 5	6
5.	ITS #2 Condenser Cooling to 216-B-3 Pond via 241-BYR-154 Diversion Box	6 in., Steel (schedule 80 and schedule 40)	Not Required; coated and wrapped	Concrete; Partial	3	10
6.	Condensate Processed by Ion Exchange Unit to 216-B Cribs	2 in., Steel (schedule 40)	Not Required; coated and wrapped	No	3	10

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APPENDIX II.1-C, Part 4

Details of 200 West Area Facilities and Operations

II.1-C, Part 4 Details of 200 West Area Facilities and Operations

The Typical Process Solution Transfers within 200 West Area are shown in Figure II.1-C-20. The interarea transfer line is shown in Figure II.1-C-21.

Plutonium Processing - Z Plant

Plutonium processing operations of Z Plant (including scrap reclamation, chemical conversion and finishing operations) produce waste streams which are routed to various processing and disposal sites. Figures II.1-C-22 and II.1-C-23 identify the waste streams produced by Z Plant and their destination when Z Plant is both in operation and standby status. Liquid waste lines emanating from Z Plant[6] are shown in Figure II.1-C-24 and described in Table II.1-C-14.

Uranium Processing - UO_3 Plant

Calcining uranyl nitrate hexahydrate (UNH) solution to produce uranium trioxide (UO_3) produces waste streams which are routed to various processing and disposal sites. Figure II.1-C-25 and II.1-C-26 identify the waste streams produced by the UO_3 Plant (224 U) and their destination, when the plant is both in operation and in standby status. Liquid waste lines emanating from the UO_3 Plant and the adjacent U Plant facilities are shown in Figure II.1-C-27 and described in Table II.1-C-15.

222-S Laboratory - REDOX

Laboratory operations yield waste streams of varying types which are routed to waste management facilities. Figure II.1-C-28 shows liquid waste lines emanating from the laboratory and their destination. The lines are described in Table II.1-C-16. Lines for unloading and transfer of liquid waste received from the 100 and 300 Areas are also shown and described in the above figure and table.

Decontamination--T Plant, Laundry and Mask Station

Active decontamination and laundry waste lines are shown in Figure II.1-C-29, and are described in Table II.1-C-17.

Evaporation/Solidification - 200 West Area

Tank farm operations, including waste solidification facilities 242-T and 242-S, produce waste streams which are routed to various processing and disposal sites. Figures II.1-C-30 and II.1-C-31 show the waste and transfer lines and are further described in Table II.1-C-18. Figure II.1-C-32 shows the details of the 242-S evaporator and associated tank farm waste transfer lines and are further described in Table II.1-C-19.

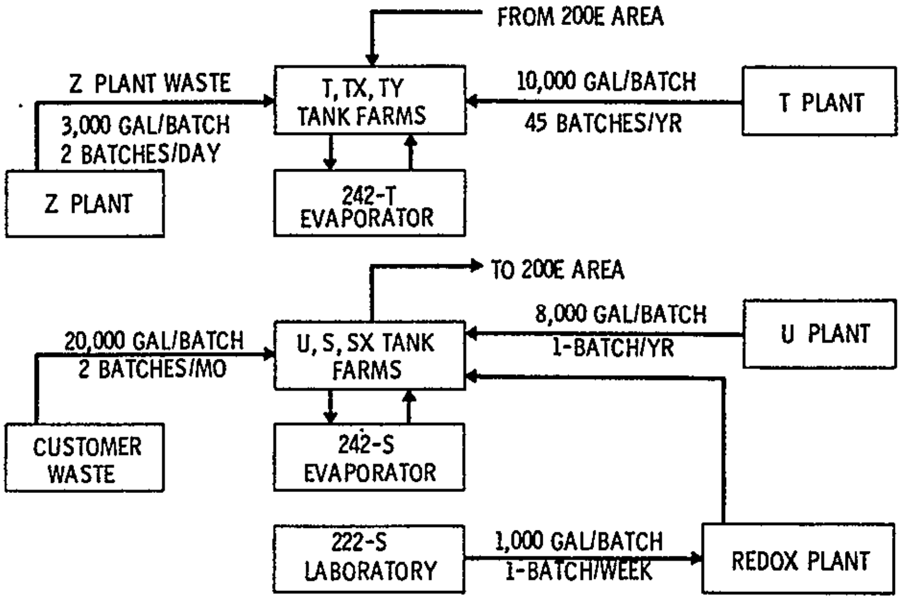


FIGURE II.1-C-20 TYPICAL PROCESS SOLUTION TRANSFERS, 200 WEST AREA

Material of Construction:	3 in. stainless tubing per ASTM A-269-47 Type 347, 3.5 in. O.D. 0.120 in. wall
Cathodic Protection:	Yes
Secondary Containment:	Concrete encased
Buried Depth:	5.5 to 16 ft
Age:	23 yr

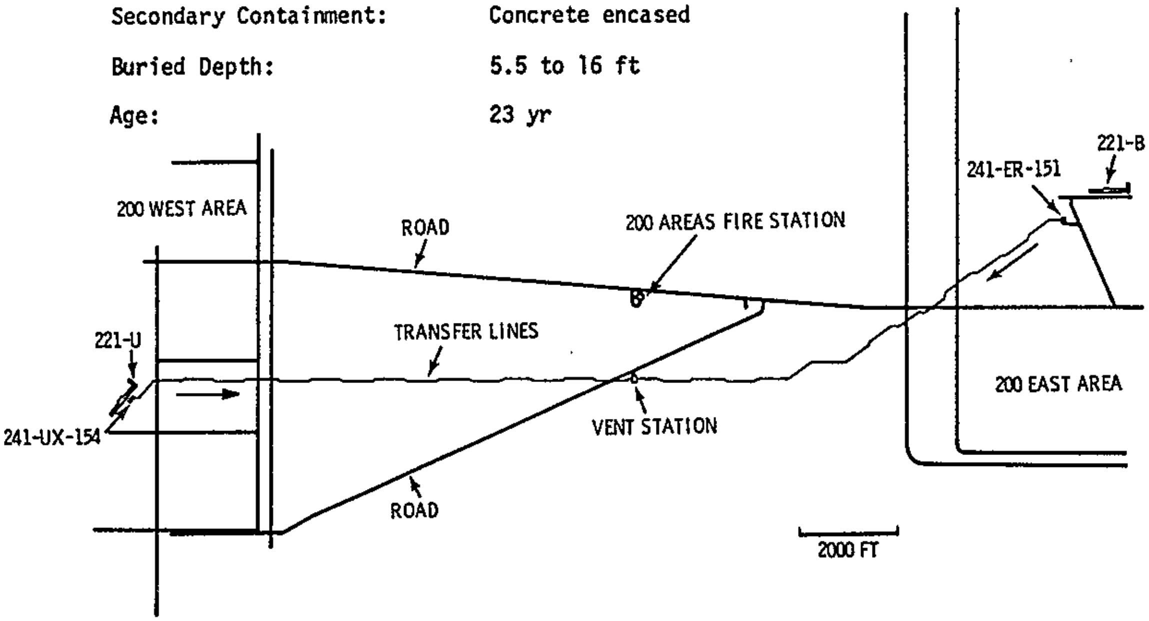


FIGURE II.1-C-21 200-E AND 200-W TRANSFER LINES

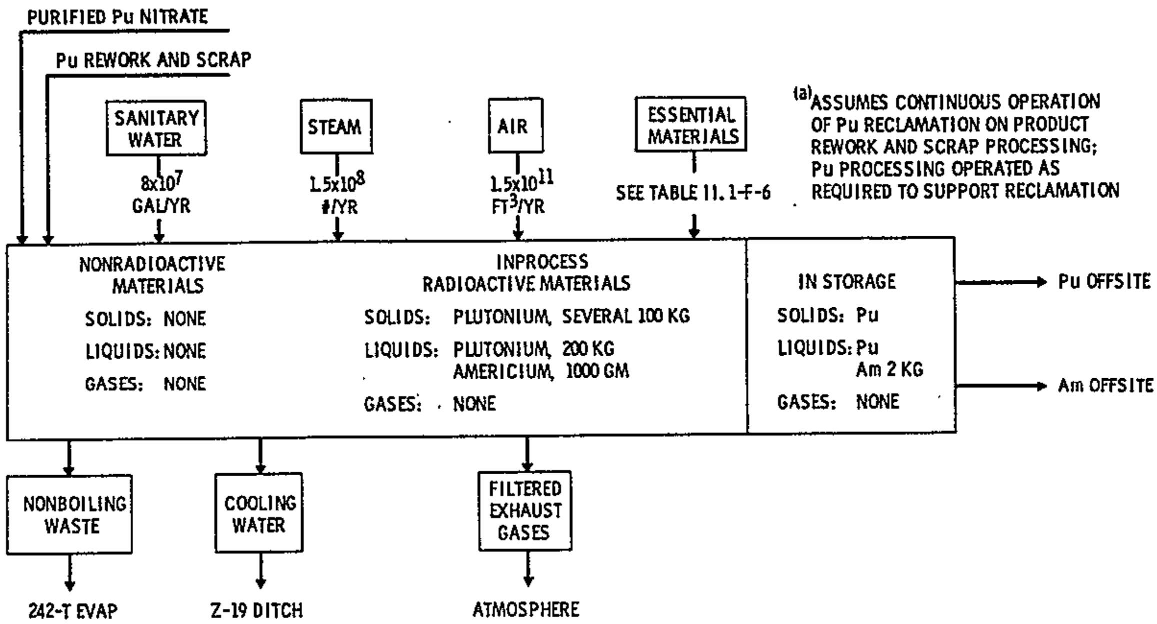


FIGURE II.1-C-22 Z PLANT INPUT-OUTPUT DIAGRAM (OPERATING)[a]

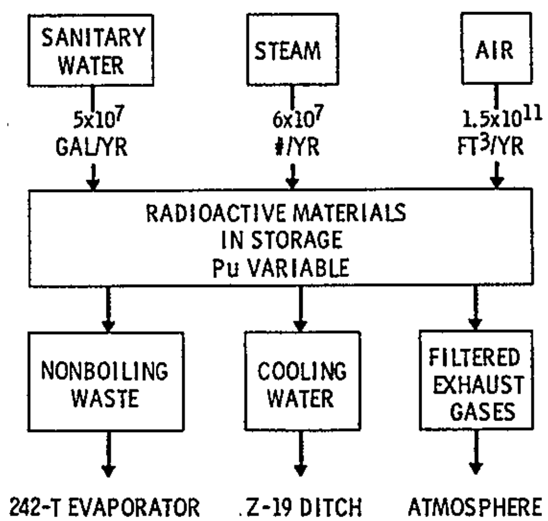


FIGURE II.1-C-23 Z PLANT INPUT-OUTPUT DIAGRAM (STANDBY)

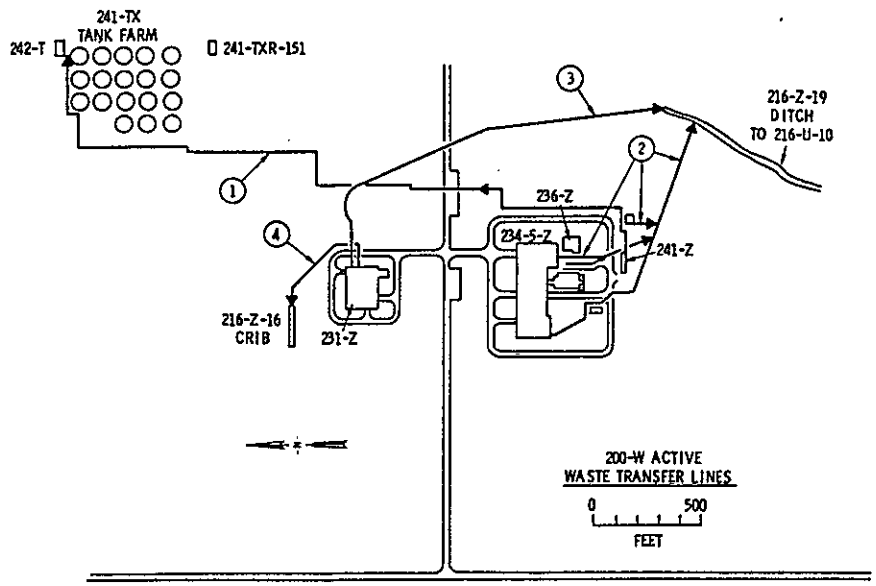


FIGURE II.1-C-24 Z PLANT

TABLE II.1-C-14

Z PLANT ACTIVE WASTE TRANSFER LINES

	Function	Description	Cathodic Protection	Secondary Containment	Buried Depth (feet)	Age (years)
1.	High Salt Waste from 234,5-Z to 242-TA Tank R-1	2 in., Stainless Steel (2)	Yes	Pipe in Pipe	3.5 to 5	1
2.	234,5-Z Cooling Water, Condensate and Chemical Sewer to 216-Z-19 Ditch	15 in., Vitrified Clay (2)	No	Concrete	3.5 to 6	12
3.	231-Z Cooling Water, Condensate and Chemical Sewer to 216-Z-19 Ditch	8 in., Vitrified Clay; 10 in., Wrought Iron	No	No	3.5 to 8	8
4.	231-Z Process Waste to 216-Z-16 Crib	3 in., Stainless Steel (3); 3 in. and 4 in., PVC	No	No	3.5 to 18	6

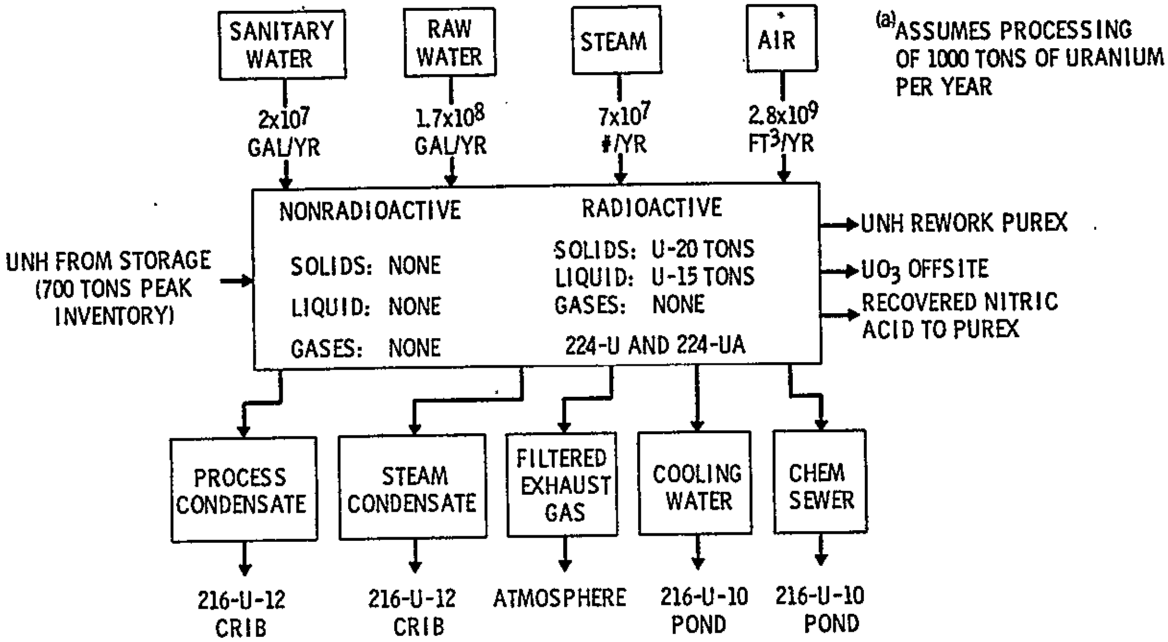


FIGURE II.1-C-25 UO_3 PLANT INPUT-OUTPUT DIAGRAM (OPERATING)[a]

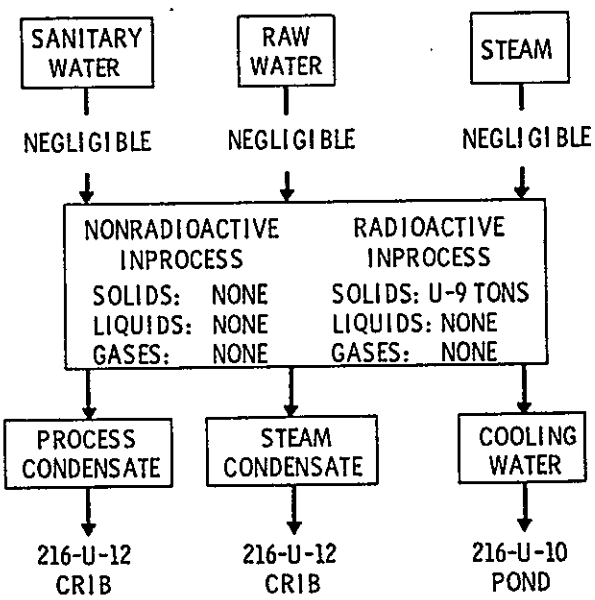


FIGURE II.1-C-26 UO_3 PLANT INPUT-OUTPUT DIAGRAM (STANDBY)

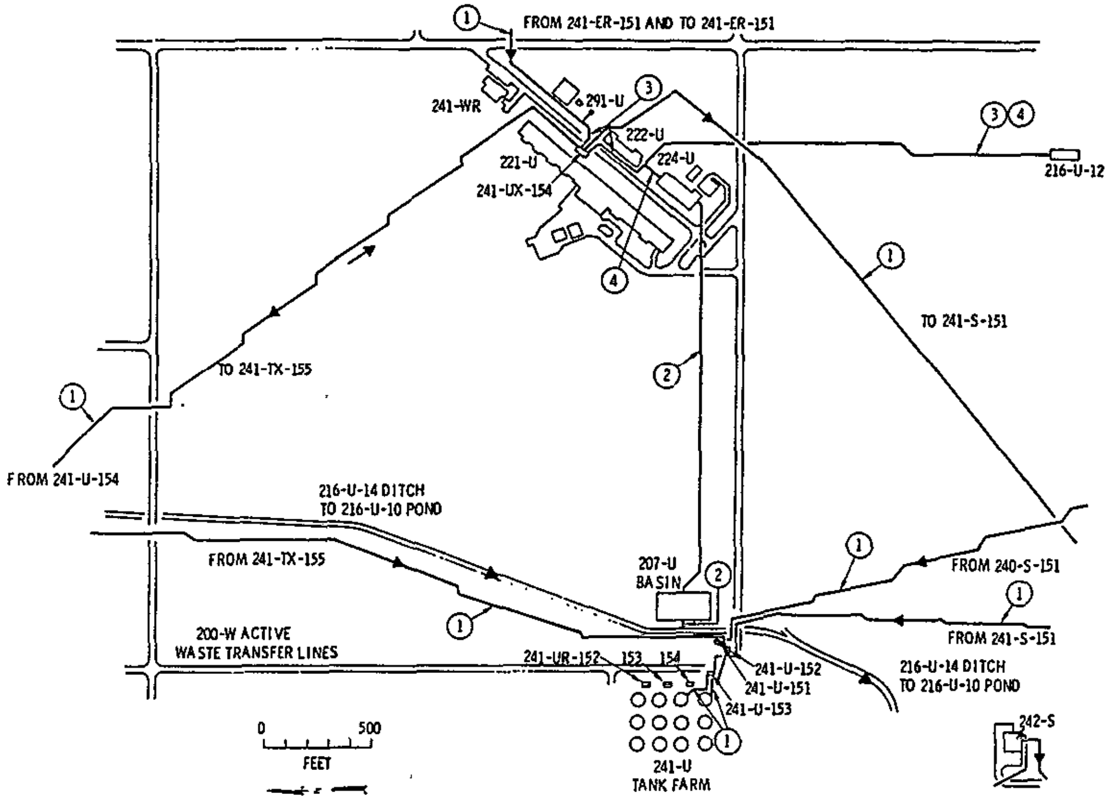


FIGURE II.1-C-27 U PLANT AND UO_3 PLANT ACTIVE WASTE TRANSFER LINES

TABLE II.1-C-15

U PLANT AND UO_3 PLANT ACTIVE WASTE TRANSFER LINES

	Function	Description	Cathodic Protection	Secondary Containment	Buried Depth (feet)	Age) (years
1.	Decontamination Solutions from 221-U to U Farm Tank 107 via Diversion Boxes 241-UX-154, 241-TX-155, 241-U-152 and 153 (Also for T Plant Waste)	3 in., Stainless Steel (11 gauge)	Partial	Concrete	8 to 18	25
2.	224-U Process Cooling Water to 216-U-14 Ditch via 207-U Retention Basins	24 in., Vitrified Clay	Not Required	No	6 to 17	20
3. 4.	291-U Stack Drain to 241-UR-154 Diversion Box, to Tie-in from 224-U Also 224-U Process Condensate to Tie-in Point for 216-U-12 Crib Line	3.5 in., Stainless Steel (schedule 40)	Yes	Partial	4 to 8	20 to 22
3,4.	Tie Point (Above) to 216-U-12 Crib	6 in., Vitrified Clay	Not Required	No	4 to 19	14 to 20

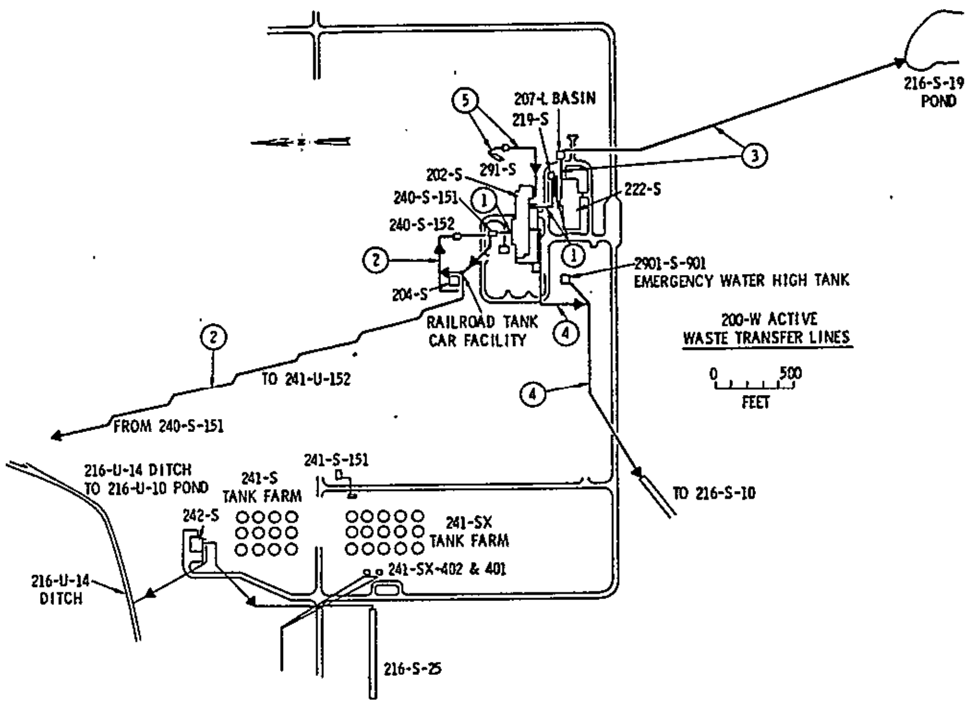


FIGURE II.1-C-28 REDOX PLANT AND 222-S LABORATORY ACTIVE WASTE TRANSFER LINES

TABLE II.1-C-16

222-S REDOX PLANT ACTIVE WASTE TRANSFER LINES

	Function	Description	Cathodic Protection	Secondary Containment	Buried Depth (feet)	Age (years)
1.	Process Waste from 222-S Lab. to 240-S-151 Diversion Box via 219-S and 202-S Buildings (to U Farm as Above)	3 in., 11 gauge Stainless; 3 in., Steel (sch. 80)	Yes	Concrete	2.5 to 23	22
2.	Railroad Tank Car Waste to U Farm Tank 107 via 204-S Tanks Pump and Diversion Boxes 240-S-152, 151 and 241-U-153	2 and 3 in. Stainless Steel (schedule 40); 3 in., Steel (sch. 80)	Yes	Yes	3 to 25	3 to 23
3.	Waste Water from 222-S Lab. to 216-S-19 Pond via 207-L Retention Basins	8 in., Vitrified Clay	Not Required	No	3.5 to 12.5	22
4.	Waste Water from 202-S and High Tank Overflow to 216-S-10 Pond	12 in., Vitrified Clay	Not Required	No	3.5 to 19	23
5.	Stack Drain Line to the 202-S Bldg.	3 in., Stainless Steel (sch. 40)	Yes	Concrete	4 to 12	23

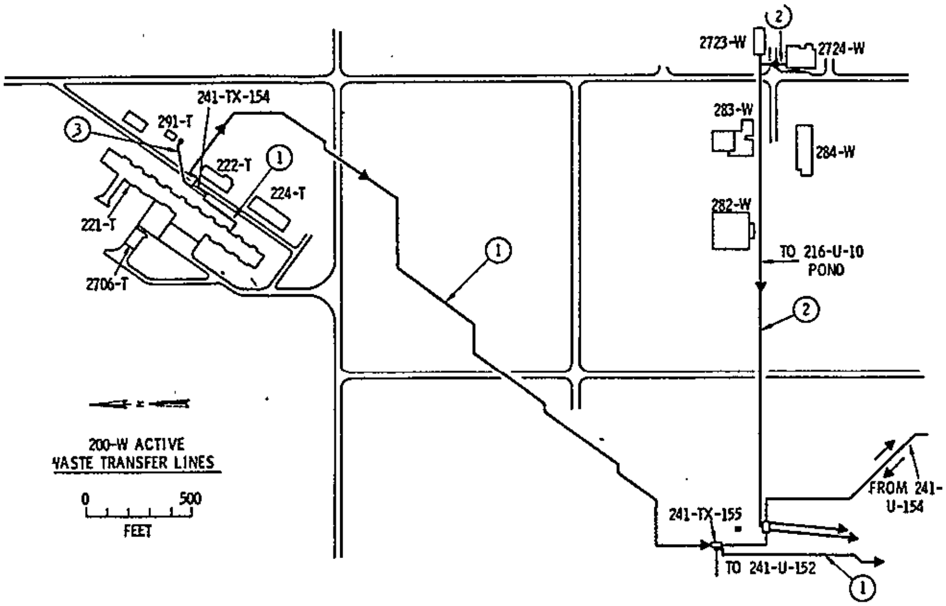


FIGURE II.1-C-29 T PLANT, LAUNDRY AND MASK STATION ACTIVE WASTE TRANSFER LINES

TABLE II.1-C-17

T PLANT, LAUNDRY AND MASK STATION ACTIVE WASTE TRANSFER LINES

	Function	Description	Cathodic Protection	Secondary Containment	Buried Depth (feet)	Age (years)
1.	Neutralized Decontamination Waste from 221-T to U Farm Tank 107 via Diversion Boxes 241-TX-154, 155 and 241-U-152, 153 (Also for U Plant Waste)	3 in., 11 gauge Stainless Steel	Partial	Concrete	8 to 18	25
2.	Waste Water from 2724-W Laundry and 2773-W Mask Cleaning to 216-U-14 Ditch	8 and 10 in. Vitreous Clay; 24, 36 and 42 in. Concrete	No	No	3.5	29
3.	Stack Condensate from 291-T	3.5 in., 11 gauge Stainless Steel	Yes	Concrete	4	30

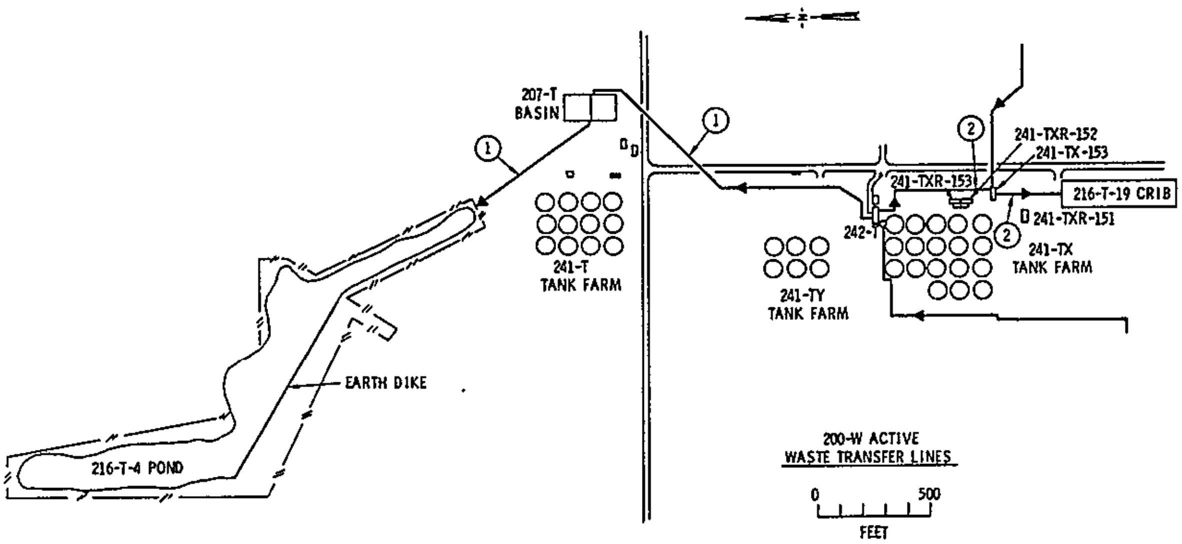


FIGURE II.1-C-30 T FARM AND EVAPORATOR ACTIVE WASTE TRANSFER LINES

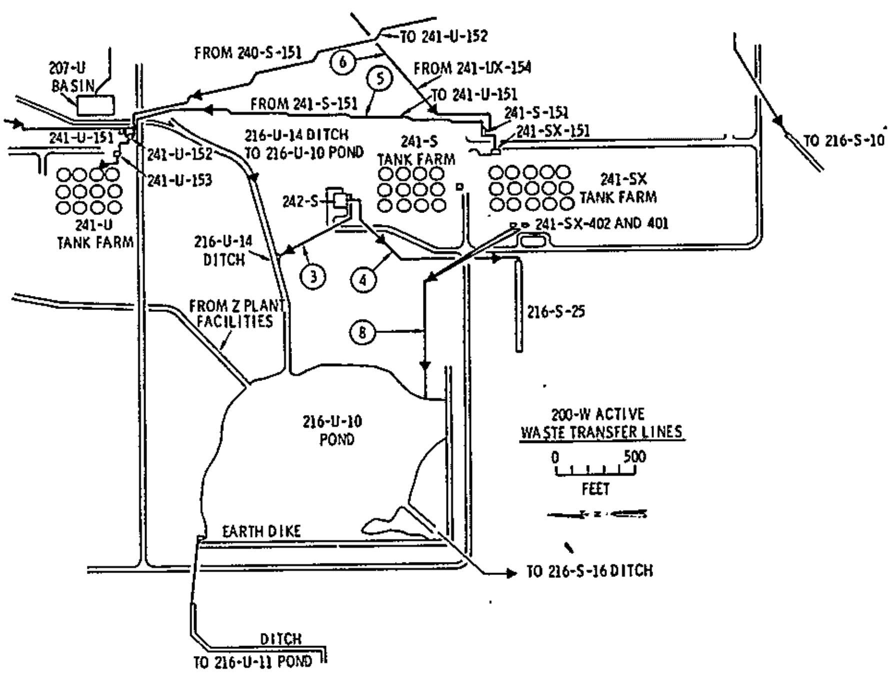


FIGURE II.1-C-31 S, SX AND U FARMS AND EVAPORATOR ACTIVE WASTE TRANSFER LINES

TABLE II.1-C-18

EVAPORATOR AND TANK FARM ACTIVE WASTE TRANSFER LINES

	Function	Description	Cathodic Protection	Secondary Containment	Buried Depth (feet)	Age (years)
1.	Cooling Water from 242-T Evaporator to 216-T-4 Pond via 207-T Retention Basins	4 in. Steel (schedule 40)	No	No	3 to 7	20
2.	Process Condensate from 242-T Evaporator to 216-T-14 Crib via 241-TX-153 Diversion Box	3.5 in. Stainless Steel; 3 in. Steel	Yes	No	3.5 to 18	18
3.	Cooling Water from 242-S Evaporator to 216-U-10 Pond via 216-U-14 Ditch	24 in. Corrugated Metal, Zinc Coated	No	No	3.5 to 8	1
4.	Process Condensate from 242-S Evaporator to 216-S-25 Crib	4 in. Steel (schedule 40)	No	No	3.5 to 8	1
5.	Process Waste Transfer Between S and SX Farms Diversion Box 241-S-151 and U Farm Box 241-U-152	3 in. Stainless Steel (18-8 Columbian)	Yes	Concrete	7 to 20	20
6.	East Area Neutralized High-Level Waste to S and SX Farms for Evaporator Feed via Diversion Boxes 241-UR-154, 241-S-151 and 241-SX-151	3 in. Stainless Steel (2) (schedule 10)	No	Concrete	3 to 18	2
7.	242-S Evaporator Supernate Feed from 241-S-02A Pump Pit; Also Slurry Discharge to S Tank Farm	2 and 3 in. Steel (schedule 40)	No	No	3 to 4.	1
8.	Condenser Cooling Water, SX Farm to 216-U-10 Pond	8 in. Steel (schedule 40)	No	No	3.5 to 5	19

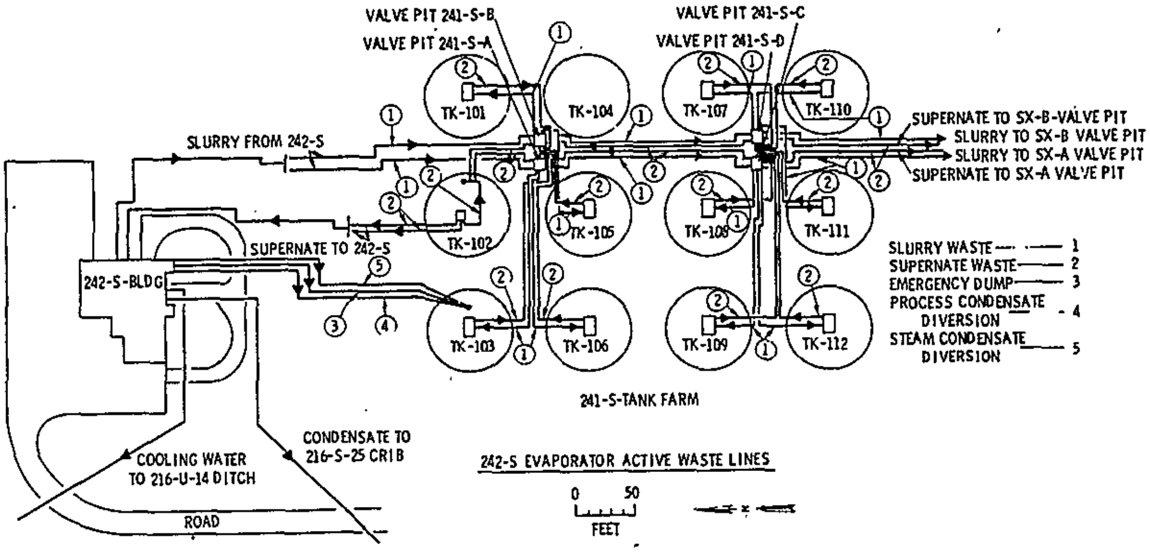


FIGURE II.1-C-32 242-S EVAPORATOR ACTIVE WASTE TRANSFER LINES

TABLE II.1-C-19

242-S EVAPORATOR AND ASSOCIATED TANK FARM WASTE TRANSFER LINES

	Function	Description	Cathodic Protection	Secondary Containment	Buried Depth (feet)	Age (years)
1.	Slurry transfer line network from 242-S to Tanks 241-S-101 through 241-S-112 via valve pits 241-S-A, B, C & D.	2 in. Carbon Steel (schedule 40, Insulated)	No	No	3 to 4	1
2.	Supernate transfer line network from Tanks 241-S-101 through 241-S-112 to 242-S via valve pits 241-S-A, B, C & D.	3 in. Carbon Steel (schedule 40, Insulated)	No	No	3 to 4	1
3.	Emergency slurry dump transfer line from 242-S Evaporator to the 241-S-103 tank	10 in. Carbon Steel (schedule 40, Insulated)	No	No	7	1
4.	Process condensate diversion transfer line from the 242-S Evaporator to the 241-S-103 Tank. Floor drain waste is also routed to the 241-S-103 tank via this line.	6 in. Carbon Steel (schedule 40, Insulated)	No	No	7	1
5.	Steam condensate diversion transfer line from 242-S to the 241-S-103 tank. Sump drainage from 242-S is also routed to the 241-S-103 tank via this line.	10 in. Carbon Steel (schedule 10, coated and wrapped)	No	No	7	1

APPENDIX II.1-C, Part 5 [RPB, X.24]

Radionuclides Stored Beneath Selected 200 Area Cribs

II.1-C.1 Ground Disposal [X.24]

At Hanford, liquid waste containing intermediate-levels of radionuclides has been discharged to the ground via structures collectively termed cribs. The cribs are subsurface liquid distribution systems from which waste solutions percolate downward through underlying sediment columns (Figure II.1-C-33). During this downward percolation, the solutions react with the sediments and nearly all of the disposed radionuclides are retained by the earth materials before reaching the water table.

The ground disposal operations at Hanford have been carried out under carefully controlled conditions. Many of these conditions were based upon laboratory studies of sediment characteristics and upon dynamic tests conducted using representative waste and soil columns.[1] Controls based on these laboratory studies have been verified by careful examination of the behavior of radionuclides in the ground beneath actual disposal sites through drilling and ground water monitoring operations.

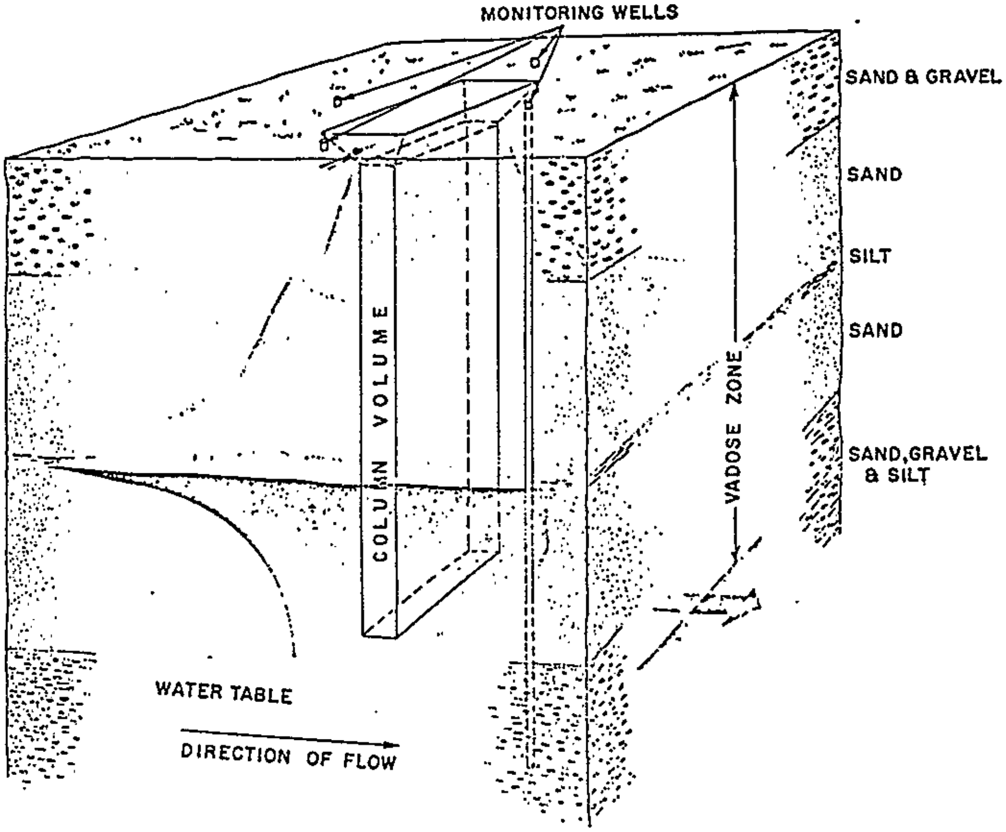


FIGURE II.1-C-33 BLOCK DIAGRAM SHOWING RELATIONSHIP BETWEEN SEDIMENTARY MATERIALS AND DISTRIBUTION OF WASTE LIQUIDS IN THE VADOSE ZONE BENEATH A TYPICAL HANFORD CRIB

II.1-C.2 Field Study of 216-S-1 and -2 Cribs Site

The most complete data regarding radionuclide migration in the vadose zone were obtained from the 216-S-1 and -2 Cribs site.[2] This disposal facility consisted of two timbered cribs buried in an excavation 11 meters (36 ft) deep, 12 meters (39 ft) wide, and 30 meters (98 ft) long. Three monitoring wells were initially drilled through the bottom area of the excavation to a depth of 46 meters (151 ft), terminating 18 meters (59 ft) above the regional water table.

This facility was in service from January 1952 until January 1956. During this four-year period approximately 1.5×10^8 liters (4.0×10^7 gallons) of waste liquid were discharged into the ground through the bottom area of the excavation. Contained in this liquid waste were an estimated 750,000 Ci of mixed fission products, including 3,000 Ci of ^{90}Sr and 2,000 Ci of ^{137}Cs. The crib was removed from service when the ^{137}Cs and ^{90}Sr concentrations in samples taken from the monitoring wells reached levels equal to ERDA Concentration Guides listed in ERDAM-0524, Annex A, Table 2, Column 2.[3]

Early in 1956, following the termination of discharges to the 216-S-1 and -2 Cribs site, an exploratory field study was undertaken to determine the spatial distribution of radionuclides in the underlying sediments. An evaluation of the field data and results from radiochemical analysis of the sediments cored from these wells was made. Three of the shallow wells located at this site were deepened and six additional research wells were drilled through the contaminated sediments. A special well logging program was initiated to detect possible changes in the radionuclide distribution pattern with time. Well logs showing profiles of gamma activity throughout the vadose zone were obtained with a scintillation counter probe. Later a neutron probe was incorporated into this monitoring zone in each well.

In 1966, 10 years after the first field exploration at the 216-S-1 and -2 Cribs site, five additional wells were drilled to determine the extent of radionuclide redistribtuion. The logging data indicated that very little change had occurred around the periphery of the crib site, so attention was focused on the sediment column directly underlying the crib excavation.

Figure II.1-C-34 shows two diagrammatic cross-sections and a plan view of the 216-S-1 and -2 Cribs site and the associated monitoring wells. The radionuclide distribution, determined at the time the crib site was removed from service in 1956, is indicated in the upper portion of Figure II.1-C-34 and the results of the 1966 evaluation are shown in the lower portion. The isoconcentration line, selected to delineate the shape of the ^{90}Sr and ^{137}Cs contamination patterns in these two cross-sections, was arbitrarily chosen at 10^{-4} μCi per gram of sediment. A schematic log of the geology beneath this area and the position of the regional unconfined water table are shown in these cross-sections. The grain size definitions for the sedimentary materials are given in Table II.1-C-20a.

The upper cross-section in Figure II.1-C-34 depicts the 1956 study results. The approximate degree of lateral spreading of liquids is indicated by the isoconcentration line at the 10^{-4} μCi/g value. Very little lateral spreading of the long-lived radionuclides had taken place, with strontium and cesium being detected in only three of the wells (299-W22-11, -15, and -18) drilled adjacent to this crib site at distances up to 35 meters (115 ft). The contamination pattern in the sediment column immediately beneath the excavated crib site was determined from the 46 meter (151 ft) depth downward by deepening the three original wells. Radiochemical analyses of sediment samples removed from the bottom of the wells showed both ^{90}Sr and ^{137}Cs present in concentrations above 10^{-4} μCi/g. Some question existed as to whether this activity resulted from radionuclide migration through the sediment column or from channeling of the liquid waste down well casings. As a result of this investigation it was concluded that the bulk of the long-lived fission products were contained in the sediments underlying the crib excavation to a depth of about 15 meters (49 ft).

The lower cross-section in Figure II.1-C-34 depicting 1966 results also shows the 10^{-4} μCi/g isoconcentration lines for ^{90}Sr and ^{137}Cs. By 1966 nearly all of the radionuclides with half-lives of less than one year had decayed to concentrations below their routine analytical detection limits. Of the nuclides with half-lives greater than one year, all were below the 10^{-4} μCi/g limit except where they were detected within the contaminated zones shown for strontium and cesium. Within these contaminated zones, the following maximum concentrations were noted: ^{60}Co, 2 x 10^{-1} μCi/g; ^{125}Sb, 1 x 10^{-1} μCi/g; and ^{106}Ru, 9 x 10^{-4} μCi/g. The concentration distribution of these nuclides followed the same general pattern as that observed for strontium and cesium. The data from these field investigations indicate that greater than 99.9% of the strontium and cesium curies discharged to this disposal site are contained within the first 5 to 10 meters (16 to 33 ft) below the bottom of the two cribs 10 years after the distribution of liquid to the facilities had been terminated.

The lower cross-section in Figure II.1-C-34 indicates that liquid waste, in draining through the sediment column, transports small yet measurable amounts of strontium and cesium downward from the zones of high concentration immediately below the cribs. The lenticular-shaped zones of strontium and cesium, designated A through E in this cross-section, probably represent sedimentary interbeds with greater capacity for removing the radionuclides from the liquid waste. Figure II.1-C-35 shows the ^{137}Cs and ^{90}Sr concentration profiles in two wells drilled through the bottom area of the 216-S-1 and -2 Cribs site. The concentrations were determined from radiochemical analyses of the sediments cored during the drilling operation. These logarithmic graphs show that the bulk of the cesium activity is in a relatively narrow zone and that the strontium activity has built up on the sediments to concentrations above 10^{-1} μCi/g over a 15 meter (49 ft) vertical section. The letter designations on these two graphs indicate the positions of the lenticular zones shown in Figure II.1-C-34.

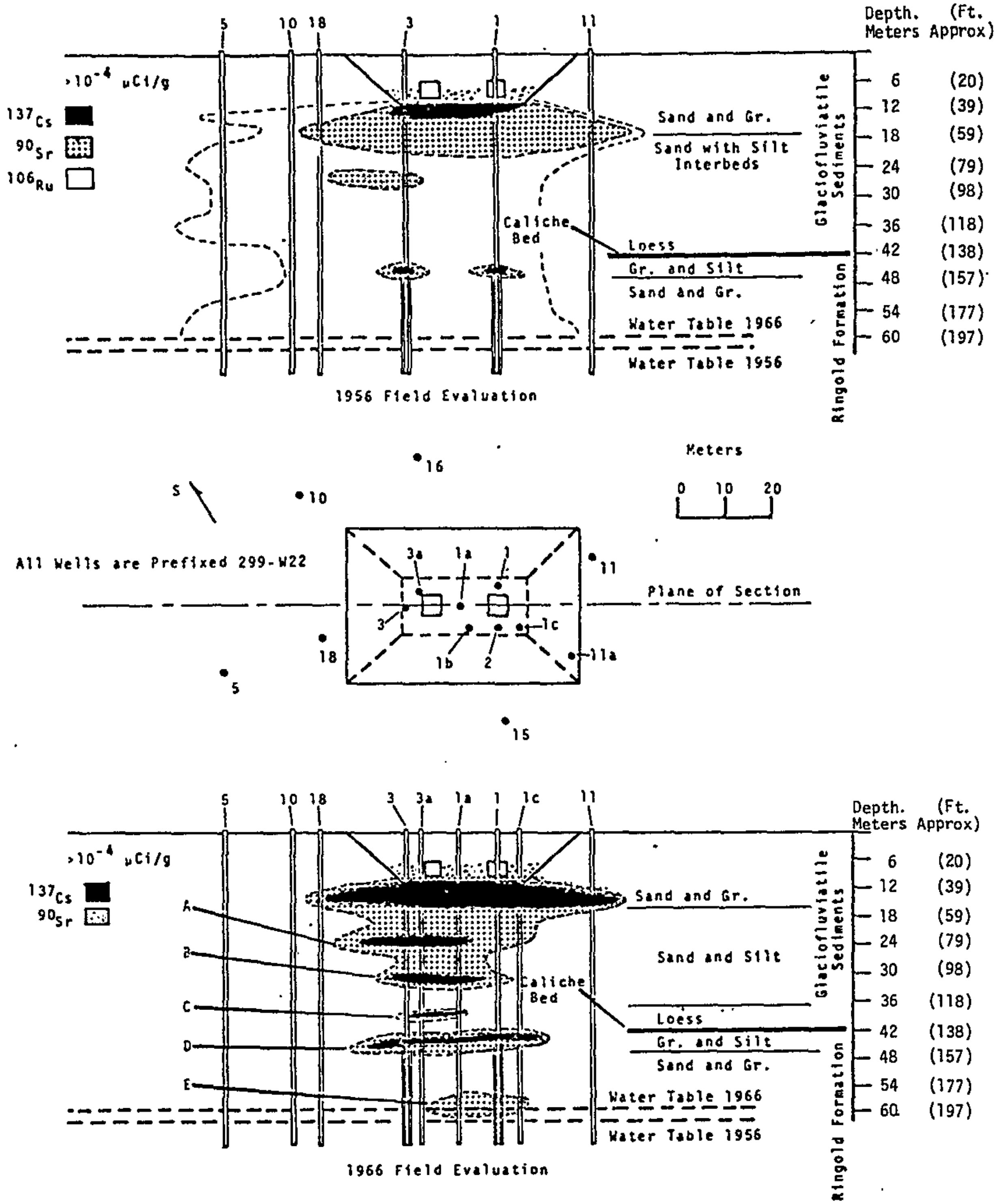


FIGURE II.1-C-34 RADIONUCLIDE DISTRIBUTION BENEATH THE 216-S-1 AND -2 CRIB SITES FROM 1956 AND 1966 FIELD EVALUATION DATA

TABLE II.1-C-20a

GRAIN-SIZE DEFINITIONS OF SEDIMENTARY MATERIALS AS USED IN THIS REPORT AND IN COMMON USAGE IN HANFORD GEOLOGIC RESEARCH[4]

Description	(sieve size) mm			in.		
Very fine clay	0.00024	to	0.00049	0.0000096	to	0.000019
Fine clay	0.00049	to	0.00098	0.000019	to	0.000038
Medium clay	0.00098	to	0.00195	0.000038	to	0.000077
Coarse clay	0.00195	to	0.0039	0.000077	to	0.00015
Very fine silt	0.0039	to	0.0078	0.00015	to	0.00031
Fine silt	0.0078	to	0.0156	0.00031	to	0.00062
Medium silt	0.0156	to	0.313	0.00062	to	0.0013
Coarse silt	0.0313	to	0.625	0.0013	to	0.0025
Very fine sand	0.0625	to	0.125	0.0025	to	0.0049
Fine sand	0.125	to	0.25	0.0049	to	0.0098
Medium sand	0.25	to	0.50	0.0098	to	0.0197
Coarse sand	0.5	to	1	0.0197	to	0.0394
Very coarse sand	1	to	2	0.0394	to	0.079
Very fine gravel	2	to	4	0.079	to	0.157
Fine gravel	4	to	8	0.157	to	0.315
Medium gravel	8	to	16	0.315	to	0.630
Coarse gravel	16	to	32	0.630	to	1.26
Very coarse gravel	32	to	64	1.26	to	2.52
Small cobbles	64	to	128	2.52	to	5.04
Large cobbles	128	to	256	5.04	to	10.08
Small boulders	256	to	512	10.08	to	20.16
Medium boulders	512	to	1024	20.16	to	40.31
Large boulders	1024	to	2048	40.31	to	80.63
Very large boulders	2048	to	4096	80.63	to	161.3

There are two possible explanations for the higher strontium and cesium concentrations at the 46 meter (151 ft) depth (Zone D in Figures II.1-C-34 and C-35). Perhaps liquid waste channeled down from the well casings to this depth, with lateral spreading taking place above the caliche horizon ($CaCO_3$) known to be present here. If bypassing down the well casings occurred, the contamination pattern shown in the lower cross-section of Figure II.1-C-34 would actually represent the migration in two disposal sites, one on top of the other.

Zones A, B, and C in Figures II.1-C-34 and II.1-C-35 show the extent of migration from beneath the crib structures while Zone E shows the migration from the liquid waste entering the ground at Zone D. The other possibility is that the selectivity of the minerals in the sediments in this zone are significantly greater for strontium and cesium than those in strata where the peak activities occur at positions A, B, and C. Experience at Hanford has shown that geologic strata underlying the Hanford Reservation have significantly different mineral contents. In Zone D beneath this disposal site, a significant change in mineralogical composition of the sediments occurs which accounts for the observed increase in radionuclides concentrations (Figure II.1-C-35). Calcium carbonate and mica are present in significant quantities. Both of these minerals are very selective for strontium and cesium ions.

Data from the well logging program indicate that the waste liquid is draining from the vadose zone beneath this disposal site. Figure II.1-C-36 shows 1) a plot of the gamma activity and moisture content in the ground beneath the 216-S-1 and -2 Cribs between the 44 meter (144 ft) and 60 meter (197 ft) depths and 2) a sediment log. In the 44 to 46 meter (144 to 151 ft) zone the sediments are predominantly sand and silt, with some gravel; below the 46 meter (151 ft) depth the materials are mostly coarser grained sands and gravels. The gamma profiles in this figure are for the years 1958, 1959, 1963, and 1966. The neutron logs presented are for the years 1965 and 1966. These were the only logging records available for this crib site. The neutron count rates were converted to percent moisture by volume.

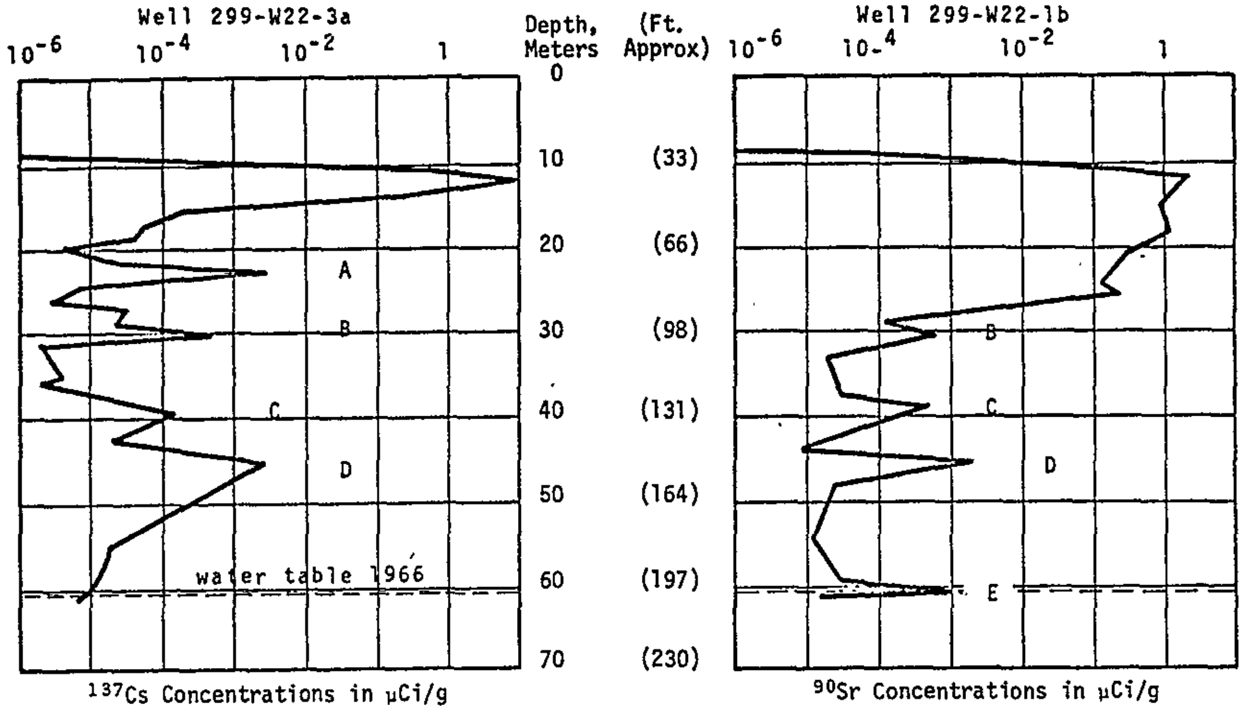


FIGURE II.1-C-35 ^{137}Cs AND ^{90}Sr CONCENTRATIONS PROFILES IN SEDIMENTS UNDERLYING THE 216-S-1 AND -2 CRIBS, 1966

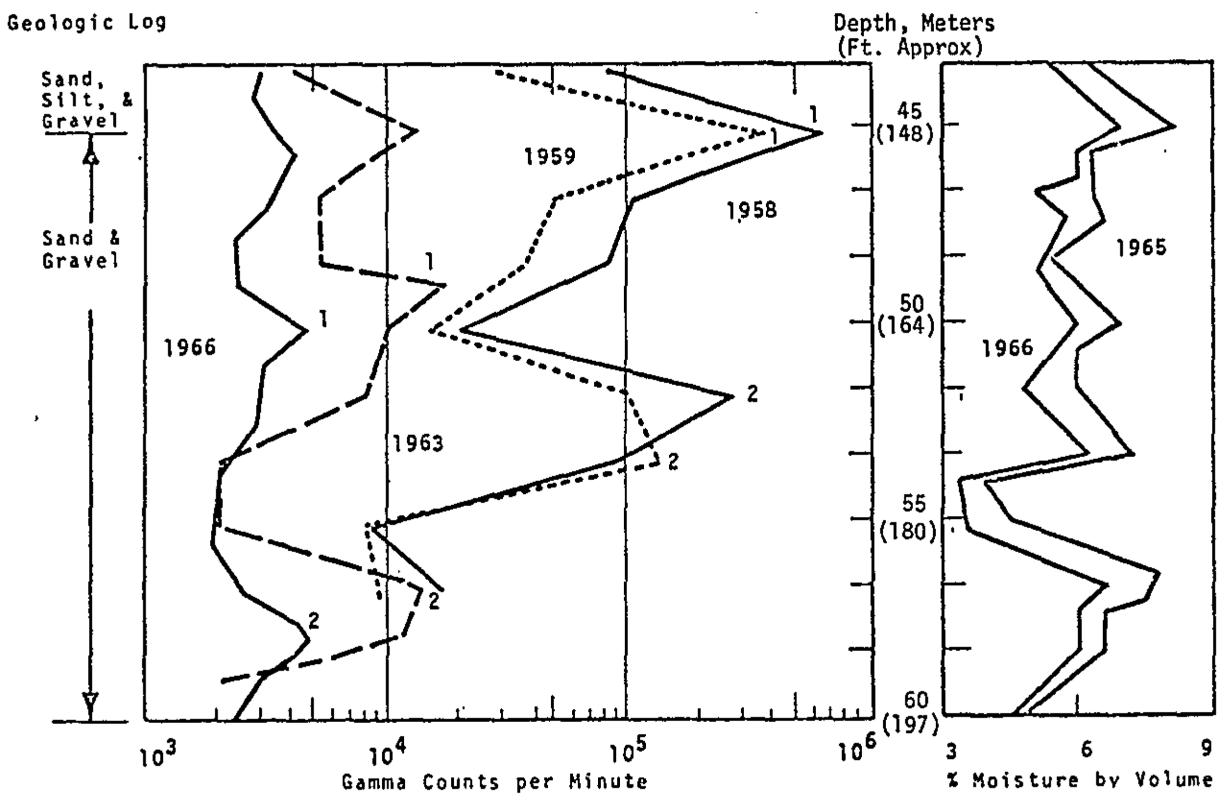


FIGURE II.1-C-36 LOGS FROM MONITORING WELLS AT THE 216-S-1 AND -2 CRIB SITES

Two distinct gamma peaks are shown on the 1958 profile; one at the 46 meter (151 ft) depth and one at the 52 meter (170 ft) depth. Each successive year the count rate decreased and the relative positions of the peaks moved progressively lower in the section (comparison of point 1 or 2 on the curves). The gamma data indicate that the activity recorded is predominantly ^{106}Ru, which has a 1-year half-life. This nuclide is not appreciably exchanged on the sediments and provides some information on the rate of movement of the liquid through the sands and gravels.

The average rate of moisture movement downward during the period 1958 to 1959 was about 1.5 meters (4.9 ft) per year. From 1959 to 1963 the average rate dropped to about 1 meter (3.3 ft) per year, then from 1963 to 1966 the downward rate averaged 0.5 meters (1.6 ft) per year. Although these data are only approximate, they do show that the rates of movement appear to be decreasing with time, as would be expected. The reduction in moisture content from 1965 to 1966 amounted to about 1% by volume.

The movement of ^{90}Sr and ^{137}Cs within the groundwater system, if such radionuclides should ever reach groundwater, would be orders of magnitude slower than the flow of the groundwater due to absorptions-desorption-absorptions on the soils, sands, and mineral through which the groundwater is flowing. To assume for an impact calculation that the materials do reach the groundwater in quantity and then move to the Columbia river so rapidly as to neglect radioactive decay is not in keeping with the facts known about the crib-groundwater-radionuclide system. To take even the minimum flow time of 15 years for water and hence about 1,500 years for ^{90}Sr and ^{137}Cs, would give about 50 half-lives of decay. These nuclides will not likely ever enter the groundwater in quantity from the cribs because no motive or driving force is present over a long enough period of time to cause a continued downward movement. If the nuclides took only 15 half-lives to reach the river, the EPA calculated dose would be reduced to 0.02 man-rem.

II.1-C.3 Additional Exploratory Drilling

In 1966 a study[4] was made to evaluate the quantity of long-lived radionuclides retained on the sediments within 25 feet (7.6 meters) of the regional water table beneath selected crib sites. Eleven major waste disposal sites (including the 216-S-1 and -2 site) were investigated by drilling and sampling the underlying sediments. The exploratory wells drilled during this study and their relationships to given cribs are listed in Table II.1-C-20b. The results of the drilling are summarized below according to the disposal site area. The 216-S-1 and -2 Cribs are not discussed here because of the more detailed information given above

TABLE II.1-C-20b

WASTE FACILITY EXPLORATORY WELLS

Disposal Site Monitored	Well Number	Depth (feet)	(Meters Approx)
216-BY-1 Crib	299 E33-1A	146	(45)
216-BY-3 Crib	299 E33-2A	233	(71)
216-BY 2 & 3 Cribs	299 E33-3A	141	(43)
216-BY-4 Crib	299 E33-4A	230	(70)
216-A-5 Crib	299 E24-1A	320	(98)
216-BC-3 Crib	299 E13-3A	338	(103)
216-BC-7 Trench	299 E13-7A	100	(31)
216-BC-17 Trench	299 E13-14A	94	(29)
216-A-24 Crib	299 E26-4A	245	(75)
216-A-8 Crib	299 E25-6A	208	(64)
216-A-8 Crib	299 E25-5A	85	(26)
216-S-1 & 2 Cribs	299 W22-1A	202	(62)
216-S-1 & 2 Cribs	299 W22-3A	207	(63)
216-S-1 & 2 Cribs	299 W22-1B	206	(63)
216-S-1 & 2 Cribs	299 W22-11A	115	(35)
216-S-1 & 2 Cribs	299 W22-1C	206	(63)
216-S-7 Crib	299 W22-14A	212	(65)
216-S-7 Crib	299 W22-13A	212	(65)
216-T-28 Crib	299 W14-2A	205	(63)
216-S-9 Crib	299 W22-26A	216	(66)
216-S-9 Crib	299 W22-27A	215	(66)
216-Z-9 Crib	299 W15-83	100	(31)
216-Z-9 Crib	299 W15-94	95	(29)
216-Z-9 Crib	299 W15-94A	50	(15)
216-Z-12 Crib	299 W18-5A	212	(65)
216-Z-12 Crib	299 W18-5B	50	(15)

216-BY Cribs. The 216-BY crib site was selected for investigation because of 1) the large amount of radioactivity disposed, 2) the nature of the waste, and 3) the location of the cribs in the northern part of 200 East Area. The eight combined cribs received $\sim 3.5 \times 10^7$ liters (9.2×10^6 gallons) of waste containing $\sim 4.4 \times 10^5$ gross beta Ci of U Plant high salt scavenged waste. The waste contained ~3000 Ci of ^{137}Cs and ~10,000 Ci ^{90}Sr.

The highest measured ^{137}Cs and ^{90}Sr concentrations were detected in Well 299-E33-2A. The highest concentration of ^{137}Cs and ^{90}Sr was ~29 μCi/g at a depth of 20 feet (6 meters) beneath the crib (Figure II.1-C-37).

216-A-5 Cribs. The 216-A-5 Crib received Purex process condensate from November 1955 to October 1961. Total disposal was ~3000 gross beta Ci (mostly ruthenium). Total water disposed was 1.8×10^9 liters. Figure II.1-C-38 shows that in Well 299-E24-1A, ^{137}Cs rapidly decreases from a concentration of 4.4×10^{-3} μCi/g at about 40 feet (12 meters). Strontium-90 was below detection limit ($\sim 1 \times 10^{-5}$ μCi/g). Ruthenium-106 was plotted to show the soil concentration in relation to the ^{137}Cs.

216-BC Cribs and Trenches. The 216-BC Cribs and trenches together received the greatest amount of radioactivity disposed at any one site on the Hanford Reservation ($\sim 9 \times 10^5$ gross beta Ci) in 1.2×10^8 liters (3.2×10^7 gallons) of tank farm and U Plant high salt scavenged waste. Of this volume, $\sim 6 \times 10^5$ Ci were disposed in 8×10^7 liters (2×10^7 gallons) to trenches on a specific retention basis. Specific retention disposal relied on a long-term storage of the waste in the pore space of the soil above the water table. Disposal volumes were much less than the total pore volume of soil beneath the trenches.

Well 216-E13-3A was drilled to a depth of 339 feet at the east edge of the BC-3 Crib. Figures II.1-C-39 and -C-40 show the ^{137}Cs, ^{90}Sr, ^{125}Sb, and ^{106}Ru concentrations as a function of depth detected in the well. Other wells drilled in the area of the BC cribs and trenches showed lesser amounts of ^{137}Cs and ^{90}Sr, except for 216-E13-14A where ^{137}Cs reached 0.22 μCi/g at 15 feet (4.6 meters) below the surface, dropping rapidly to background ($\sim 1 \times 10^{-6}$ μCi/g) below 25 feet (7.6 meters). Apparently the bulk of the long-lived radionuclides are retained from 150 to 200 feet (46 to 61 meters) above the water table at the BC location south of 200 East Area.

216-A-8 Crib. An estimated 1000 Ci of long-lived isotopes ^{137}Cs and ^{90}Sr were disposed at this Crib. Two test wells were drilled near the inlet end of the Crib. Only low levels of radioactive contamination were detected in the drilling samples. Cesium-137 concentrations were below detection limits ($\sim 1 \times 10^{-6}$ μCi/g) in both wells below 40 feet (12 meters). Strontium-90 concentrations were less than 3×10^{-4} μCi/g at depths greater than 25 feet (7.6 meters) in both wells.

216-A-24 Crib. The waste disposed of between May 1958 and December 1965 contained an estimated 500 Ci of ^{137}Cs and 80 Ci of ^{90}Sr. The highest measured ^{137}Cs concentration (~0.5 μCi/g) and ^{90}Sr concentration ($\sim 6 \times 10^{-3}$ μCi/g) occurred at 19 feet (5.8 meters) below the ground surface in a well drilled at the inlet end of the Crib.

216-T-28 Crib. The 216-T-28 Crib received a total of $\sim 42 \times 10^6$ liters (11×10^6 gallons) of waste containing $\sim 6 \times 10^4$ gross beta Ci prior to the site investigation. A well drilled adjacent to the corner of this facility showed peak concentrations of 2.5×10^{-3} ~Ci ^{137}Cs/g of soil at 32 feet (9.7 meters) below the surface.

216-S-7 Cribs. This facility consisted of two 50-foot (15 meter) square timbered cribs operated in parallel. A replacement for the S-1 and -2 Cribs, it received 3.8×10^3 liters (1.0×10^3 gallons) and $\sim 3.0 \times 10^5$ gross beta Ci between January 1956 and July 1965. This waste contained approximately 3000 Ci of ^{90}Sr and 500 Ci of ^{137}Cs. A maximum ^{137}Cs concentration of 13 μCi/g of soil and ^{106}Ru concentration of 18 μCi/g of soil occurred at 21 feet (6.4 meters) below ground surface in a well drilled 25 feet (7.6 meters) from the center of one of the cribs (Figure II.1-C-41). Strontium-90 concentration peaked at ~3 μCi/g, also at 21 feet (6.4 meters) (Figure II.1-C-42). The nuclide concentrations dropped sharply and were less than detection limits ($<1 \times 10^{-4}$ μCi/g) below 150 feet (45.7 meters). Results in a second well drilled adjacent to the other crib showed peak concentrations of ^{137}Cs at 1.5×10^2 μCi/g and ^{90}Sr of $\sim 6 \times 10^{-2}$ μCi/g of soil. Concentrations of the nuclides beyond 150 feet (45.7 meters) beneath the surface were below detection limits.

216-S-9 Crib. The 216-S-9 Crib facility was drilled after having received $\sim 3.0 \times 10^7$ liters (7.9×10^6 gallons) of waste containing ~9000 gross beta Ci. Two wells showed only a low level of ^{90}Sr ($\sim 1 \times 10^{-5}$ μCi/g) at 140 feet (42.7 meters), with no long-lived nuclides detected below that level.

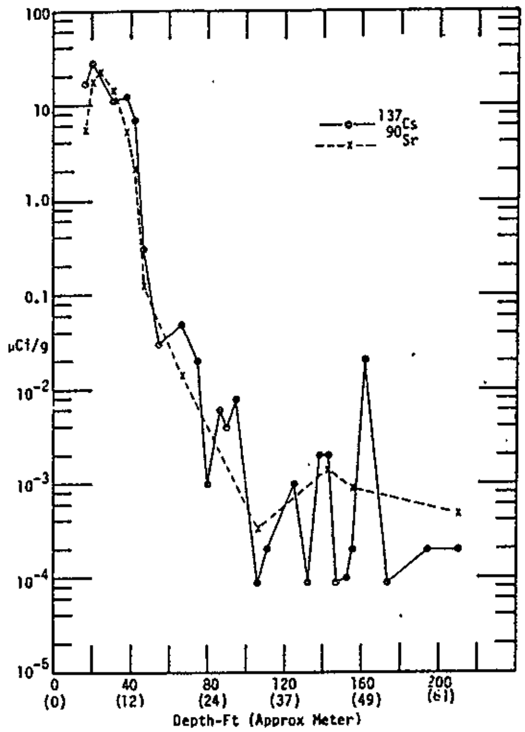


FIGURE II.1-C-37 RADIONUCLIDE CONCENTRATION AS A FUNCTION OF DEPTH, WELL E33-2A

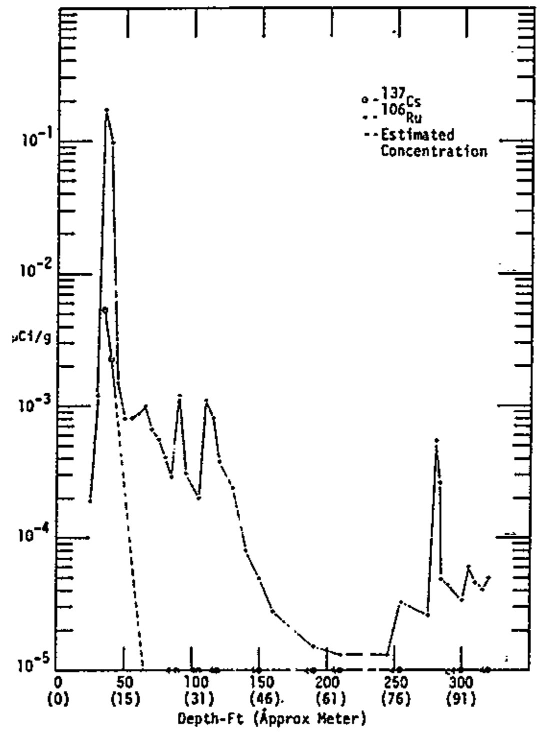


FIGURE II.1-C-38 RADIONUCLIDE CONCENTRATION AS A FUNCTION OF DEPTH, WELL E24-1A

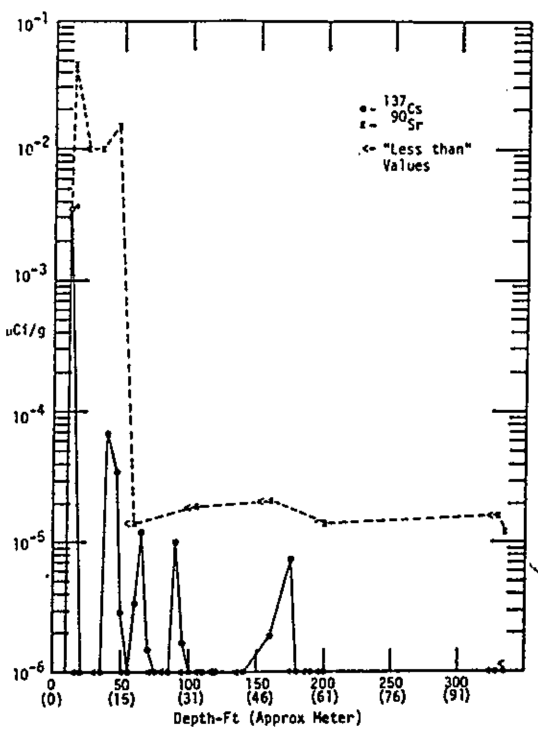


FIGURE II.1-C-39 RADIONUCLIDE CONCENTRATION AS A FUNCTION OF DEPTH, WELL E13-3A (^{137}Cs and ^{90}Sr)

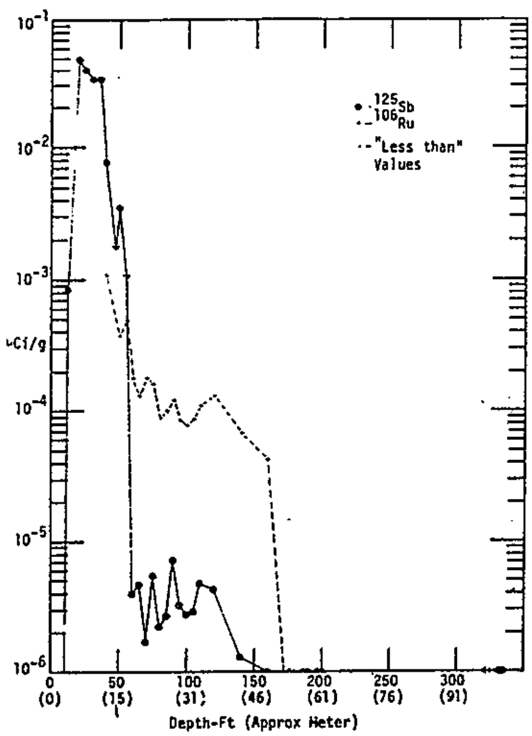


FIGURE II.1-C-40 RADIONUCLIDE CONCENTRATION AS A FUNCTION OF DEPTH, WELL E13-3A (^{125}Sb and ^{106}Ru)

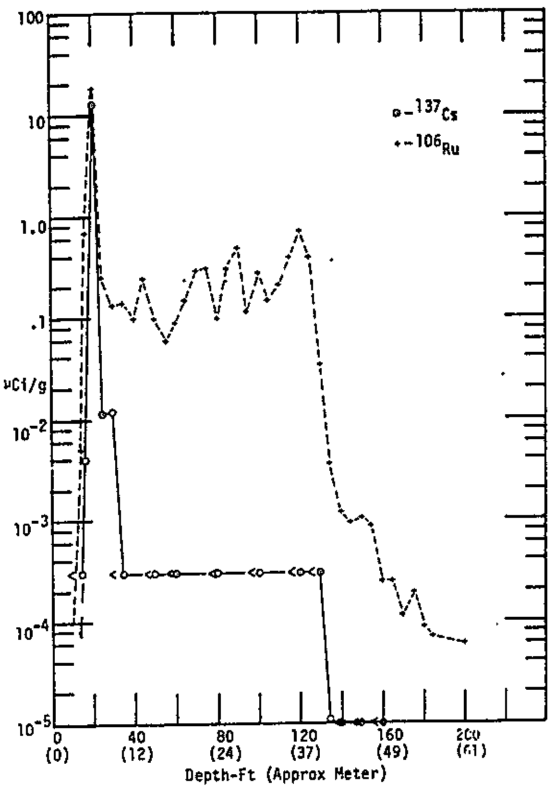


FIGURE II.1-C-41 RADIONUCLIDE CONCENTRATION AS A FUNCTION OF DEPTH, WELL W22-13A (^{137}Cs and ^{106}Ru)

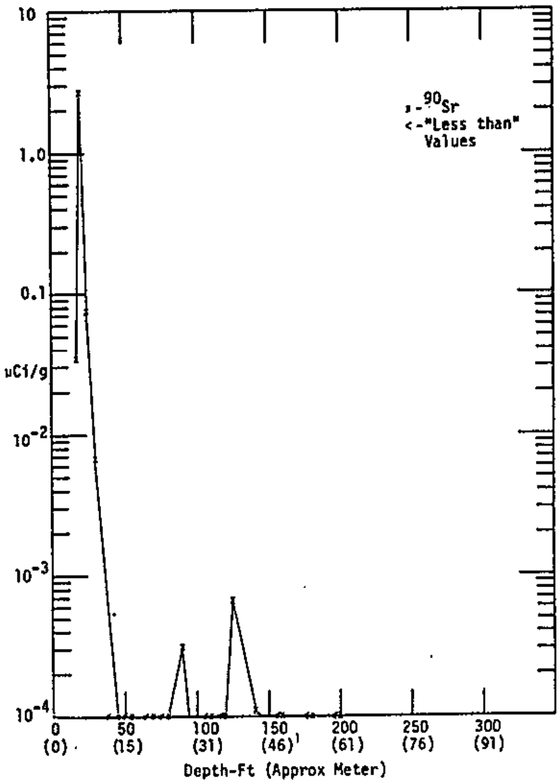


FIGURE II.1-C-42 RADIONUCLIDE CONCENTRATION AS A FUNCTION OF DEPTH, WELL W22-13A (^{90}Sr)

216-Z-9, 216-Z-12. Wells drilled around the periphery of the 216-Z-9 and 216-Z-12 Cribs indicated that sediments located a short distance beyond the boundaries of the Cribs had been only slightly contaminated with alpha by the lateral spread of the waste liquids.

Gable Mountain and B Plant Ponds. Although these waste waters are normally uncontaminated, equipment malfunction has infrequently allowed some radiocontaminants to enter the ponds. A well drilled at the east end of B Pond showed a very low ^{137}Cs concentration (5×10^{-6} μCi/g of soil). A well drilled at the north side of Gable Mountain Pond showed no long-lived radionuclides in the soil samples.

II.1-C.4 Inventory Estimates Above the Water Table

In 1967[4] the results from the additional exploratory drilling in 1966 at 11 major crib sites were used to estimate the maximum concentration of long-lived radiocontaminants (^{60}Co, ^{137}Cs, and ^{90}Sr) contained in the soil column 25 feet (7.6 meters) above the existing water table at waste disposal facilities in the 200 East Area and 20 feet (6.1 meters) above the facilities in the 200 West Area.

A total of ~27 curies of ^{90}Sr, ~17 curies of ^{137}Cs and ~15 curies of ^{60}Co were estimated present within a 25 foot (7.6 meters) zone and 20 foot (6.1 meters) above the water table in the 200 East and 200 West Areas, respectively.

In 1971 an empirical relationship was developed from which quantities of cesium, strontium, and ruthenium in the lowermost 50 feet (18 meters) of the vadose zone above the water table were estimated. Forty-two cribs (Figure II 1-C-43 and Table II.1-C-20c) were identified where quantities of these radionuclides were discharged to ground. The total inventory calculated for the lowest 50 feet (18 meters) of the vadose zone was about 2000 Ci of ruthenium and about 400 Ci of strontium plus cesium.

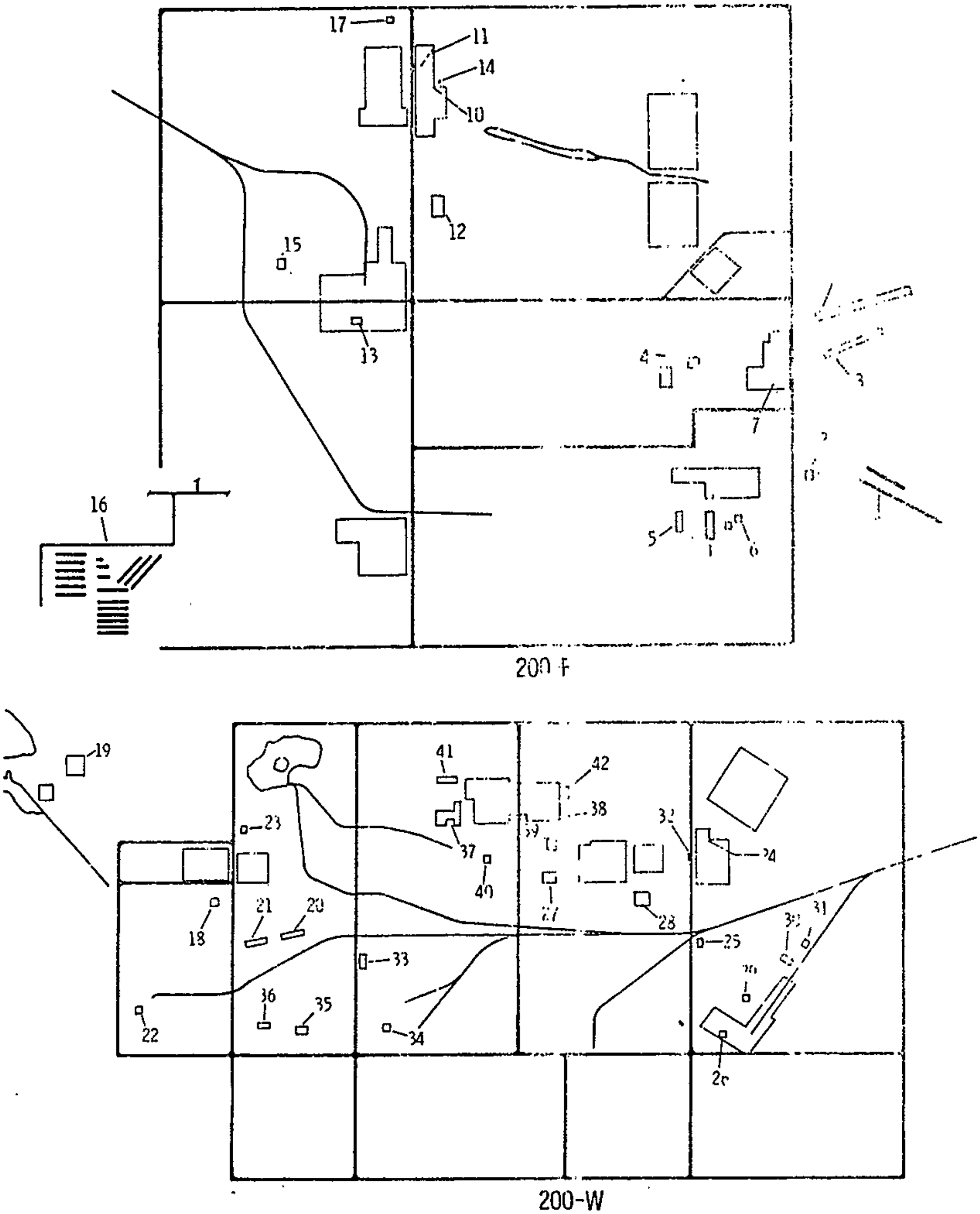


FIGURE II.1-C-43 CRIBS HAVING CONCENTRATIONS OF RUTHENIUM, STRONTIUM, AND CESIUM IN THE LOWERMOST 50 FEET (15 METERS) OF THE VADOSE ZONE

TABLE II.1-C-20c

ESTIMATE OF WASTE VOLUMES IN THE VADOSE ZONE

Site No.	Official Designation and Waste Description	Number of Site Monitoring Wells	Depth to Ground-water, ft (Approx Meters)	Column Volumes of Waste Discharged
1	216-A-5 Process Condensate	5	310 (95)	102
2	216-A-6 Steam Condensate	1	270 (82)	148
3	216-A-8 Tank Farm Condensate	7	260 (79)	20
4	216-A-9 N-Reactor Decontamination Wastes & Acid Fractionator Wastes	4	295 (90)	80
5	216-A-10 Process Condensate	2	315 (96)	112
6	216-A-21 Ammonia Scrubber and Laboratory Wastes	1	315 (96)	11
7	216-A-23A & B 241-A Fan House Drain	0	295 (90)	85
8	216-A-24 Tank Farm Condensate	5	260 (79)	45
9	216-A-30 Steam Condensate	3	295 (90)	46
10	216-B-7 224-B Building Waste, 5-6 Cell Drain & 221-B Construction Water	3	220 (67)	6
11	216-B-8 224-B Building Waste, 5-6 Cell Drain & 2nd Cycle Waste	9	220 (67)	0.5
12	216-B-9 5-6 Cell Drain & 2nd Cycle Waste	8	270 (82)	0.6
13	216-B-10A 222-B Building & 292-B Building Wastes 216-B-10B B-Plant R-13 Building Wastes	1	295 (90)	0.9
14	216-B-11A & B 242-B Building Condensates	2	220 (67)	4
15	216-B-12 U-Plant & B-Plant Process Condensates	5	295 (90)	30
16	216-B-14 through 216-B-34 and 216-B-52 Scavenged Waste 216-B-53A & B, 216-B-54 and 216-B-58 300 Area Laboratory Waste	22	325 (99)	0.6
17	216-B-43 through 216-B-49 Scavenged Wastes 216-B-50 ITS Waste	11	215 (66)	0.5
18	216-S-1 & 216-S-2 Redox Process Condensate	20	200 (61)	42
19	216-S-6 Steam Condensate	1	190 (58)	67
20	216-S-7 Process Condensate	4	210 (64)	47
21	216-S-9 Process Condensate	4	200 (61)	23
22	216-S-20 222-S Building & 300 Area Laboratory Wastes	0	220 (67)	390
23	216-S-21 Tank Farm Condensate	1	190 (58)	22
24	216-T-5 2nd Cycle Wastes & 241-T-112 Tank Waste 216-T-7 224-T Building, 5-6 Cell Drain & 2nd Cycle Wastes 216-T-32 224-T Building Waste	14	200 (61)	7
25	216-T-6 224-T Building & 5-6 Cell Drain	11	240 (73)	8
26	216-T-8 222-T Building Laboratory Waste	0	280 (85)	0.06
27	216-T-19 224-T Building, 242-T Building, 5-6 Cell Drain, 2nd Cycle, & Waste Evaporator Wastes	5	190 (58)	7
28	216-T-26 Scavenged Waste 216-T-27 Decontamination, Scavenged and 300 Area Laboratory Wastes 216-T-28 Decontamination and 300 Area Laboratory Wastes	6	200 (61)	0.8
29	216-T-33 224-T Building & 2706 Building Wastes	1	240 (73)	22
30	216-T-34 300 Area Laboratory Waste	2	240 (73)	1
31	216-T-35 300 Area Laboratory Waste	4	220 (67)	0.2
32	216-T-36 Decontamination Waste	2	200 (61)	0.05
33	216-U-1 & 216-U-2 Decontamination Wastes	1	220 (67)	12.7
34	216-U-4A & B 222-U Building Laboratory Waste	0	240 (73)	12.5
35	216-U-8 Process Condensate & Stack Drain	4	240 (73)	40
36	216-U-12 Process Condensate & Stack Drain	3	240 (73)	13
37	216-Z-1 & 216-Z-2 D-6 Tank, 236 Building and 242 Building Wastes 216-Z-3 D-6 Tank Waste 216-Z-1A, B, & C 236 Building & 242 Building Low-Salt Waste	20	190 (58)	3
38	216-Z-5 231 Building Process Wastes & 300 Area Laboratory Wastes	9	200 (61)	1
39	216-Z-7 231 Building & 300 Area Laboratory Wastes	7	200 (61)	3
40	216-Z-9 Recuplex Low-Salt Waste	8	190 (58)	0.5
41	216-Z-12 D-6 Tank Waste	8	190 (58)	9
42	216-Z-16 231 Building Laboratory Waste	2	200 (61)	74

II.1-C.5 Exploratory Drilling in Actinide Trenches

Since 1966, additional exploratory wells have been drilled through the bottom areas of two inactive actinide trenches containing greater than 10 kg of pu; the 216-Z-9 Trench and the 216-Z-1A Tile Field.

II.1-C.5.1 216-Z-9

The 216-Z-9 Trench (Figure II.1-C-44) is an enclosed underground cavern which received actinide-bearing waste liquids (~4 x 10^6 liters) from plutonium processing operations between 1955 and 1962. A detailed examination of the distribution of actinides within the first 60 cm (24 in.) of sediments below the trench floor was carried out in 1973.[5] The locations of the access holes from which the sediment samples were obtained are shown in Figure II.1-C-44. The region of measured maximum actinide concentration was in the vicinity of access holes B, G, and H. In 1974, bore hole "H" was drilled to a depth of 14 meters (46 feet). The approximate concentrations as a function of depth are given below.

ACTINIDE CONCENTRATION, "G" BORE HOLE

Depth Below Trench Floor	^{239}Pu µCi/liter of sediment	^{241}Am µCi/liter
2 cm (0.8 in.)	1 x 10^6	1 x 10^5
30 cm (12 in.)	1 x 10^4	1 x 10^3
60 cm (24 in.)	6 x 10^3	6 x 10^2

ACTINIDE CONCENTRATION, "H" BORE HOLE

Depth Below Trench Floor	^{239}Pu µCi/liter of sediment	^{241}Am µCi/liter
5 cm (2 in.)	1 x 10^6	1 x 10^5
30 cm (12 in.)	6 x 10^3	1 x 10^2
7 m (23 ft)	9 x 10^1	3 x 10^1
14 m (46 ft)	<9 x 10^{-1}	1 x 10^{-1}

In general, the concentration of ^{239}Pu in the "H" bore hole decreases by two orders of magnitude from the 5-cm (2.0 inches) to the 30-cm (12 inches) depth and by four orders of magnitude from the 30-cm (12 inches) depth to the 14-m (46 feet) depth. The water table lies at a depth of approximately 30 meters (98 feet) below the bottom of the "H" hole.

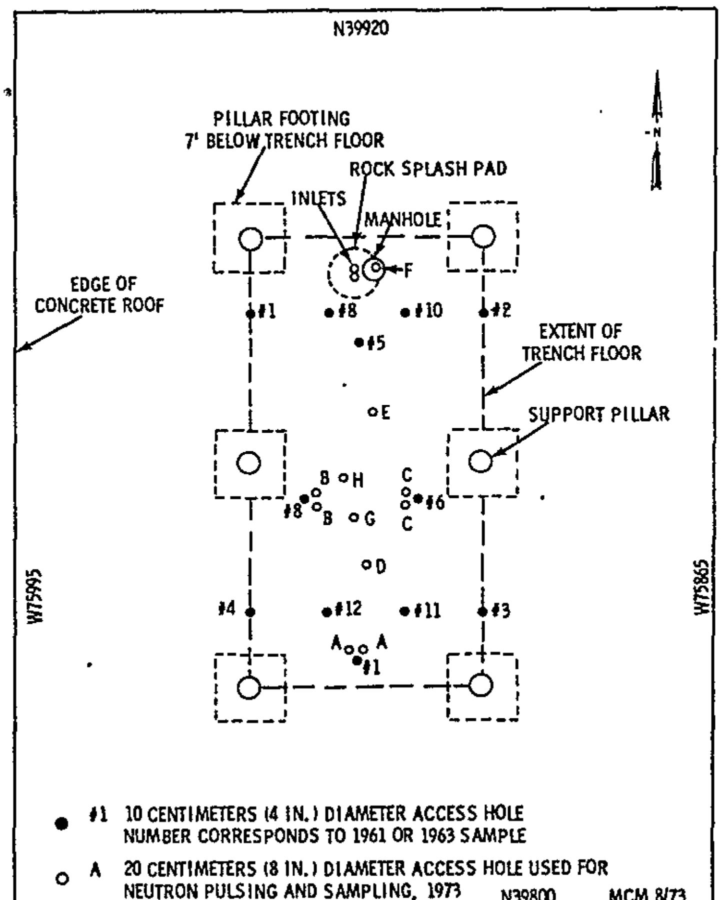


FIGURE II.1-C-44 216-Z-9 TRENCH SHOWING LOCATIONS OF ACCESS HOLES

The location of mineral-waste reactions associated with alpha activity was defined by the exposure of prepared 216-Z-9 sediment samples to alpha-sensitive film.[6] Figure II.1-C-45 shows several positive prints from these films. In positive prints of the film negatives (autoradiographs), areas of high alpha concentration appear black. Sediment grains associated with areas of alpha contamination were subsequently identified by electron microprobe analysis. The alpha activity generally appears to be associated with reaction rims enclosing fragments of metamorphic and basaltic sediment grains.

II.1-C-5.2 216-Z-1A

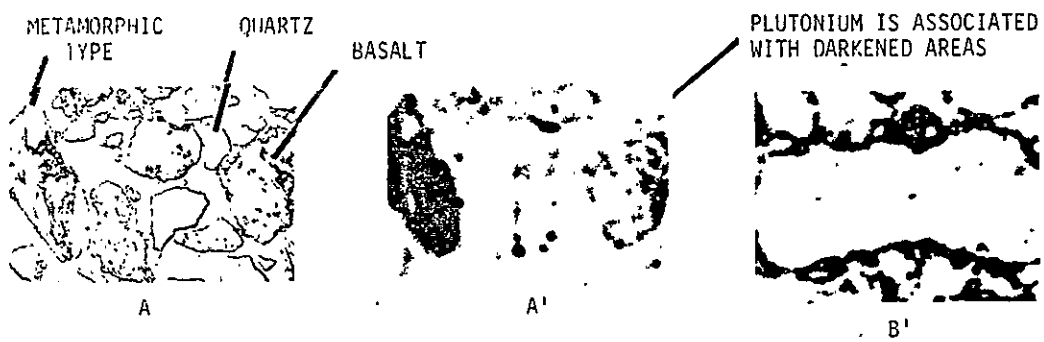
The 216-Z-1A facility (Figure II.1-C-46) is an underground tile field lying approximately 3.5 meters (12 feet) below the ground surface. The site received actinide-bearing liquid waste [$\sim 6 \times 10^6$ liters (1.5×10^6 gallons)] from the plutonium processing operations between 1956 and 1969. In 1974, two wells were drilled through the bottom of the tile field at the head-end ("a" test hole) and at the far-end ("c" test hole) of the central distributor pipe (Figure II.1-C-46).

Analyses of sediment samples from these wells indicate that the greatest measured concentration of actinides occurs within 0.5 meters (1.6 feet) below the bottom of the distributor pipe. The approximate concentrations of plutonium and americium determined from bore hole samples are given below:

Depth Below Bottom of Tile Field meters	"a" Test Hole		"c" Test Hole	
	^{239}Pu µCi/liter of sediment	^{241}Am µCi/liter of sediment	^{239}Pu µCi/liter of sediment	^{241}Am µCi/liter of sediment
0.5 (1.6 ft.)	3×10^4	$\sim 1 \times 10^3$	1×10^4	$\sim 2.0 \times 10^2$
2 (7 ft.)	4×10^2	$\sim 4 \times 10^1$	9×10^2	$\sim 8 \times 10^1$
8 (26 ft.)		$\sim 3 \times 10^1$	6×10^0	$\sim 4.5 \times 10^1$
11 (36 ft.)		$\sim 3.5 \times 10^1$	$<1 \times 10^0$	$\sim 4.0 \times 10^1$

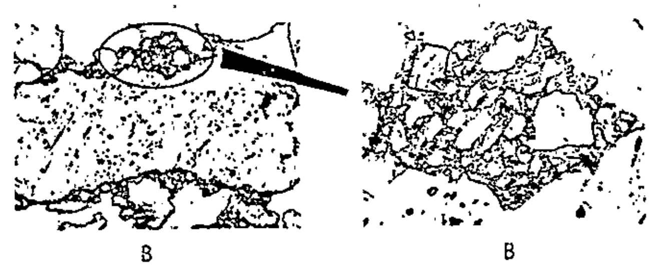
Concentrations of plutonium below the 2-m (7 feet) depth at the "a" site are below the limit of detection of the analytical method then employed ($<4 \times 10'$ µCi/liter) for the routine analysis of these sediment samples. In general, the concentration of ^{239}Pu in the "c" test well decreases four orders of magnitude from the 0.5-m (1.6 feet) depth to the 11 meter (36 feet) depth. The water table lies at a depth of approximately 40 meters (130 feet) below the bottom of the "c" test well.

Autoradiographic examination revealed that the mineral waste reactions occurring in the sediment beneath the 216-Z-1A are also associated with the altered surfaces of metamorphic and basaltic rock fragments (Figure II.1-C-45) similar to those observed samples from the 216-Z-9 site.



A. Selective Concentration of Alpha Emitters by Rock Type and/or Mineral

A & B Are Photomicrographs
A' & B' Are Alpha Sensitive Autoradiographs



B. Disintegration of Basalt Fragment Due to Chemical Attack by Acid Waste

FIGURE II.1-C-45 AUTORADIOGRAPHS OF SEDIMENT GRAINS

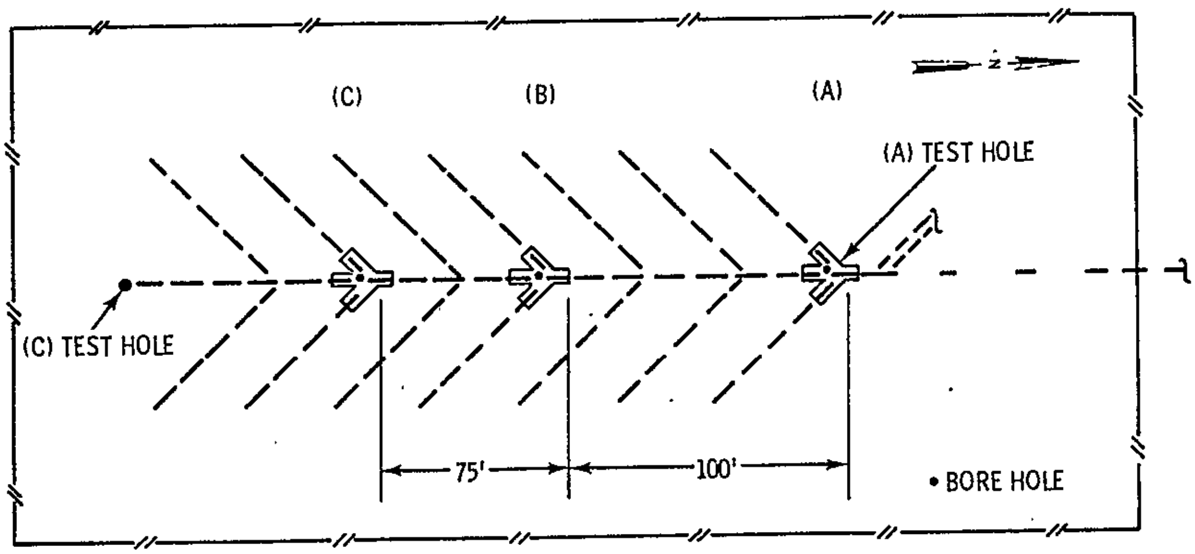


FIGURE II.1-C-46 216-Z-1A SHOWING LOCATIONS OF DISCHARGE POINTS

II.1-C REFERENCES

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2. D. J. Brown, "Migration Characteristics of Radionuclides Through Sediments Underlying the Hanford Reservation," Proceedings of a Symposium May 29 - June 2, 1970, jointly organized by the IAEA and ENEA, Vienna, Austria, 1967.

3. Energy Research and Development Administration Guides, Manual Chapter 0524, Annex A, Table 2, Column 2.

4. National Research Council "Report of the Subcommittee on Sediment Terminology," Trans. American Geophysics Union, Vol. 28, No. 6, December 1947.

5. A. E. Smith, Nuclear Reactivity Evaluations of 216-Z-9 Enclosed Trench, ARH-2915, Atlantic Richfield Hanford Company, December 1973.

6. L. L. Ames, Jr., Characterization of Actinide Bearing Soils, Top Sixty Centimeters of 216-Z-9 Enclosed Trench, BNWL-1812, Battelle Pacific Northwest Laboratories, Richland, WA, 1974.

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APPENDIX II.1-C, Part 6 [X.25]

Estimated Inventories

TABLE II.1-C-21

TANK WASTE INVENTORY SUMMARY 1968-1980 (IN MILLIONS OF GALLONS)

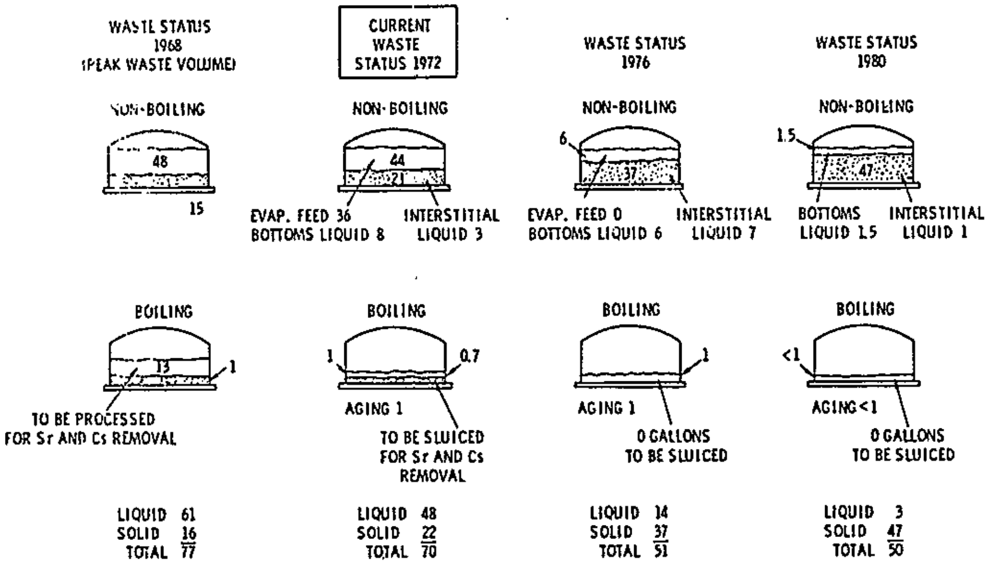

TABLE II.1-C-22

ESTIMATED INVENTORY AND CHARACTERISTICS OF SOLIDS STORED IN TANKS - YEAR 1980[a]

	Salt Cake		High Heat Sludge (SX Farms)	Other Sludges
Gallons (Millions)	38		0.6	8
Number of Tanks	73		7	72
Radionuclides (Ci/gal)[b]				
^{137}Cs	0.6		5.0	0.3
^{90}Sr	3×10^{-2}		50	2
^{239}Pu	4×10^{-4}		4×10^{-3}	6×10^{-4}
Average Composition (wt%)				
	In Tank Solidified Waste	Neutralized Waste		
Chemical				
$NaNO_3$	80	20	45	75
$NaNO_2$	4	1	7	4
NaOH	10	1	5	1
$NaAlO_2$	1	2	20	-
Na_2CO_3	2	1	10	-
Other				
(Fe, SO_4, PO_4)	1	25	3	18
Water of Hydration	2	50	10	2
Bulk Density (g/cc)	1.8	1.8	2.0	2.0

(a) Currently the tanks contain approximately the following amounts of actinides: uranium-865 metric tons, thorium-15 metric tons, plutonium-380 kg and neptunium-7.5 kg. Much smaller quantities of americium and curium are present in the tanks, and trace quantities of other actinides may exist in the tanks.
(b) The estimated inventories (or concentrations) of radionuclides are reported to one significant figure to reflect the uncertainty in the data.

TABLE II.1-C-22a

MAJOR CHEMICALS (METRIC TONS)

LIQUID PHASE							SOLID PHASE					
$NaOH$	$NaAlO_2$	$NaNO_3$	$NaNO_2$	Na_2CO_3	$NaPO_4$	Volume, gal	$NaNO_3$	$NaNO_2$	$NaOH$	$NaAlO_2$	Na_2CO_3	Volume, gal
A FARM												
1000	1000	2000	1000	60	30	2,360,000	500	40	50	5	20	147,000
AX, AY FARM												
600	800	1000	800	200	20	3,520,000	1000	50	200	30	30	306,000
B FARM												
400	600	1000	500	100	20	1,720,000	10000	500	2000	200	300	2,550,000
BY FARM												
1000	2000	2000	1000	300	30	2,910,000	20000	1000	2000	200	500	4,450,000
BX FARM												
300	500	600	600	200	10	1,790,000	5000	400	1000	100	200	1,510,000
C FARM												
400	500	900	200	900	50	2,760,000	5000	400	1000	100	200	1,690,000
S FARM												
2000	1000	2000	1000	300	30	2,380,000	20000	1000	3000	300	500	4,960,000
SX FARM												
1000	1000	4000	1000	200	20	4,110,000	5000	500	500	3000	1000	1,770,000
T FARM												
90	80	300	200	90	20	754,000	10000	400	1000	100	200	2,220,000
TX FARM												
1000	3000	9000	3000	500	300	5,590,000	30000	1000	3000	300	500	6,220,000
TY FARM												
100	200	700	200	40	20	476,000	4000	200	400	40	100	749,000
U FARM												
100	200	900	100	60	40	1,280,000	3000	200	400	40	50	674,000

(a) The chemical characteristics for individual tanks within each farm do not vary significantly from the average for the entire farm. All tanks contain large concentrations of sodium nitrate, sodium hydroxide, sodium nitrite, and sodium aluminate. While records are available on the past history on chemical characteristics of the contents of all waste tanks, the task of compiling these voluminous data into report form would be costly and time consuming.

TABLE II.1-C-22b

SX TANK FARM VOLUME AND CONTENTS[(a)]

(January 1975)

Tank (SX)	Sludge Volume, K Gal	Liquid Volume, K Gal	Contents
101	466	457	242-S terminal liquor
102	117	492	242-S bottoms supernatant
103	79	850	Dilute evaporator feed
104	139	787	Dilute evaporator feed
105	37	899	Dilute evaporator feed
106	1	237	Dilute evaporator feed
107	109	0	Dry sludge/air cooling
108	87	0	Dry sludge/air cooling
109	257	0	Dry sludge/air cooling
110	32	388	Dilute evaporator feed
111	125	0	Dry sludge/air cooling
112	106	0	Dry sludge/air cooling
113	6	0	Dry sludge
114	200	0	Dry sludge/air cooling
115	6	0	Dry sludge

(a) Tanks 102 through 106-SX contained nonboiling waste and are to be used for 242-S salt cake storage. Tanks 107 through 115-SX formerly contained boiling waste. Tank 101-SX is currently being used to store terminal liquor from the 242-S Evaporator.

The 108-SX prototype sludge cooler successfully demonstrated the concept of air cooling sludges. A permanent sludge cooling facility has been provided for the 241-SX boiling waste tanks. Air is drawn through each tank to a common exhauster header. The exhaust air is preheated, filtered to remove particulate matter, and discharged via a centrifugal blower to the atmosphere. The air flow to each tank is controlled by butterfly valves. The current plan is to solidify the liquids and continue to air-cool the hotter sludges until a final disposal method is developed.

Other than the A and AX Tanks, most tanks containing sludges have never been scheduled to be sluiced since the concentration of strontium is sufficiently low that removal is not necessary. Since Tank 105-A, which has leaked, contains sludges which do have high concentration of strontium, the need and procedures for removing the sludge are being evaluated.

Principal documents are available related to sludge retrievability or safe management:

G. E. Backman, et al., Chemical Processing Department Hazards Evaluation In-Tank Waste Solidification - Project CAC-965, RL-SEP-65, November 1964.

P. Hatch, et al., Chemical Processing Department Hazards Evaluation, TK-108-SX Stabilization Prototype, ISO-937, June 1967.

F. K. Pittman, Plan for the Management of AEC-Generated Radioactive Wastes, WASH-1202, July 1973.

TABLE II.1-C-23

ESTIMATED INVENTORIES[(a)] RADIOACTIVE LIQUID WASTE TO GROUND 200 AREAS

Decay Through 1972 (From Startup) 200 East

	Units	To Ponds and Ditches	To Cribs	To Specific Retention Sites	Total[(b)]
Volume	(l)	0.3×10^{12}	0.2×10^{11}	0.1×10^{9}	0.3×10^{12}
Pu	(g)	$<0.7 \times 10^{3}$	0.1×10^{5}	0.4×10^{3}	0.1×10^{5}
Beta	(Ci)	0.6×10^{4}	0.6×10^{5}	0.4×10^{5}	0.1×10^{6}
^{90}Sr	(Ci)	0.1×10^{4}	0.1×10^{5}	0.8×10^{4}	0.2×10^{5}
^{106}Ru	(Ci)	$<0.3 \times 10^{2}$	0.2×10^{4}	0.3×10^{3}	0.3×10^{4}
^{137}Cs	(Ci)	0.4×10^{3}	0.8×10^{4}	0.1×10^{5}	0.2×10^{5}
^{60}Co	(Ci)	$<0.3 \times 10^{2}$	0.1×10^{3}	0.2×10^{2}	$<0.2 \times 10^{3}$
U	(kg)	$<1.0 \times 10^{4}$	0.3×10^{5}	0.5×10^{5}	0.8×10^{5}
^{233}U	(g)	$<0.5 \times 10^{3}$	0.5×10^{3}		$<1.0 \times 10^{4}$

Decayed Through 1972 (From Startup) 200 West

	Units	To Ponds and Ditches	To Cribs	To Specific Retention Sites	Total[(b)]
Volume	(l)	0.2×10^{12}	0.1×10^{11}	0.8×10^{8}	0.2×10^{12}
Pu	(g)	0.8×10^{4}	0.8×10^{5}	0.9×10^{5}	0.2×10^{6}
Beta	(Ci)	0.4×10^{3}	0.3×10^{5}	0.2×10^{5}	0.5×10^{5}
^{90}Sr	(Ci)	$<0.1 \times 10^{3}$	0.6×10^{4}	0.2×10^{3}	0.7×10^{4}
^{106}Ru	(Ci)	$<0.2 \times 10^{1}$	0.9×10^{2}	0.2×10^{1}	0.9×10^{2}
^{137}Cs	(Ci)	$<0.9 \times 10^{2}$	0.5×10^{4}	0.1×10^{5}	0.2×10^{5}
^{60}Co	(Ci)	$<0.9 \times 10^{1}$	0.3×10^{2}	0.3×10^{1}	$<0.4 \times 10^{2}$
U	(kg)	$<0.6 \times 10^{4}$	0.4×10^{5}	0.1×10^{4}	0.4×10^{5}
^{233}U	(g)				

Decayed Through 1972 (From Startup) Total 200-E + 200-W

	Units	To Ponds and Ditches	To Cribs	To Specific Retention Sites	Total[(b)]
Volume	(l)	0.5×10^{12}	0.3×10^{11}	0.2×10^{9}	0.5×10^{12}
Pu	(g)	0.9×10^{5}	0.9×10^{5}	0.9×10^{5}	0.2×10^{6}
Beta	(Ci)	0.7×10^{4}	0.9×10^{5}	0.6×10^{5}	0.2×10^{6}
^{90}Sr	(Ci)	0.2×10^{4}	0.2×10^{5}	0.8×10^{4}	0.3×10^{5}
^{106}Ru	(Ci)	$<0.3 \times 10^{2}$	0.2×10^{4}	0.3×10^{3}	0.3×10^{4}
^{137}Cs	(Ci)	0.5×10^{3}	0.1×10^{5}	0.2×10^{5}	0.4×10^{5}
^{60}Co	(Ci)	$<0.4 \times 10^{2}$	$<0.2 \times 10^{3}$	0.2×10^{2}	$<0.2 \times 10^{3}$
U	(kg)	$<0.7 \times 10^{4}$	0.6×10^{5}	0.5×10^{5}	0.1×10^{6}
^{233}U	(g)	$<0.5 \times 10^{3}$	0.5×10^{3}		$<1.0 \times 10^{4}$

(a) The estimated inventories (or concentrations) of radionuclides are reported to one significant figure to reflect the uncertainty in the data. Where the estimated inventories are noted as less than (<), the recorded inventory is based on the analytical limit of detection.
(b) Totals do not necessarily equal the sum of individual contributions because of rounding of the data.

TABLE II.1-C-24

ESTIMATED DECAYED STATUS OF SOLID WASTE[a] BURIAL GROUNDS IN THE 200 AREAS THROUGH 1972

BURIAL GROUND 200 EAST AREA	VOLUME (CUBIC FEET)	URANIUM (GRAMS)	PLUTONIUM (GRAMS)	TOTAL (CURIES)	^{90}Sr (CURIES)	^{137}Cs (CURIES)	^{106}Ru (CURIES)
DRY WASTE NO. 001	1.1×10^5	4×10^5	9×10^2	5×10^0	1×10^0	1×10^0	9×10^{-7}
DRY WASTE NO. 12A	5.4×10^5	1×10^6	9×10^3	7×10^1	1×10^1	2×10^1	3×10^{-1}
DRY WASTE NO. 12B	2.6×10^5	7×10^3	1×10^3	2×10^3	2×10^2	2×10^2	6×10^1
MINOR CONSTRUCTION NO. 4	5.6×10^4	1×10^3	1×10^1	5×10^{-1}	1×10^{-1}	1×10^{-1}	2×10^{-6}
CONSTRUCTION (NO NUMBER)	8.0×10^4	2×10^3	2×10^1	6×10^{-1}	1×10^{-1}	2×10^{-1}	3×10^{-5}
222 VAULTS	6.0×10^3	1×10^3	1×10^0	3×10^1	7×10^0	8×10^0	6×10^{-6}
INDUSTRIAL WASTE NO. 002	3.2×10^5	3×10^5	8×10^2	1×10^3	3×10^2	3×10^2	6×10^{-4}
INDUSTRIAL WASTE NO. 005	1.1×10^5	1×10^5	6×10^2	4×10^2	1×10^2	1×10^2	2×10^{-3}
INDUSTRIAL WASTE NO. 05Z	2.2×10^5	1×10^5	1×10^3	1×10^3	2×10^2	2×10^2	3×10^{-2}
INDUSTRIAL WASTE NO. 010	5.3×10^5	8×10^5	5×10^3	5×10^4	4×10^3	5×10^3	2×10^3
TOTAL 200-E[b]	2.2×10^6	3×10^6	2×10^4	6×10^4	5×10^3	6×10^3	2×10^3

BURIAL GROUND 200 WEST AREA	VOLUME (CUBIC FEET)	URANIUM (GRAMS)	PLUTONIUM (GRAMS)	TOTAL (CURIES)	^{90}Sr (CURIES)	^{106}Ru (CURIES)	^{137}Cs (CURIES)	OTHER RADIOACTIVE (CURIES)
DRY WASTE NO. 001	2.5×10^5	7×10^5	9×10^4	9×10^0	2×10^0	2×10^{-6}	2×10^0	
DRY WASTE NO. 002	3.0×10^5	1×10^6	1×10^5	3×10^1	6×10^0	1×10^{-4}	7×10^0	
DRY WASTE NO. 003	3.9×10^5	7×10^7	7×10^4	5×10^1	1×10^1	3×10^{-3}	1×10^1	
222-T VAULTS	2.4×10^3	3×10^2	3×10^{-1}	4×10^1	9×10^0	9×10^{-6}	1×10^1	
222-S VAULTS	5.6×10^3	7×10^2	7×10^{-1}	2×10^2	5×10^1	6×10^{-3}	6×10^1	
INDUSTRIAL WASTE NO. 001	4.8×10^5	9×10^5	2×10^3	2×10^3	6×10^2	1×10^{-3}	6×10^2	
INDUSTRIAL WASTE NO. 002	6.7×10^5	2×10^6	6×10^3	2×10^4	3×10^3	1×10^2	4×10^3	
DRY WASTE NO. 03A	1.8×10^5	9×10^6	4×10^3	1×10^5	3×10^2	1×10^2	3×10^2	1×10^5
DRY WASTE NO. 04A	6.2×10^5	5×10^8	4×10^4	3×10^2	5×10^1	2×10^0	5×10^1	
DRY WASTE NO. 04B	3.0×10^5	4×10^6	2×10^4	2×10^5	3×10^2	9×10^1	3×10^2	2×10^5
CAISSON - NO. 1	2.2×10^2	2×10^5	5×10^2	1×10^2	1×10^1	2×10^0	2×10^1	
CAISSON - NO. 2	8.0×10^0		$5 \times 10^-$	3×10^0	4×10^{-1}	8×10^{-2}	4×10^{-1}	
CAISSON - NO. 3	1.7×10^2	1×10^5	5×10^2	3×10^3	3×10^2	8×10^1	4×10^2	
CAISSON - NO. 4	5.4×10^1	5×10^4	7×10^2	1×10^4	1×10^3	4×10^2	1×10^3	
CAISSON - ALPHA 1	2.0×10^2	4×10^4	1×10^3	4×10^4	7×10^2	4×10^2	7×10^2	1×10^4
TOTAL 200-W[b]	3.2×10^6	6×10^8	4×10^5	4×10^5	7×10^3	1×10^3	7×10^3	3×10^5
TOTAL 200 AREAS[b]	5.4×10^6	6×10^8	4×10^5	5×10^5	1×10^4	3×10^3	1×10^4	3×10^5

(a) The estimated inventories or concentration of radionuclides are reported to one significant figure to reflect the uncertainty in the data.
(b) Totals do not necessarily equal the sum of individual contributions because of rounding of the data.

TABLE II.1-C-25

PUREX EQUIPMENT STORAGE TUNNELS[a] INVENTORY[b]--SEPTEMBER 30, 1973

	Tunnel No. 1	Tunnel No. 2	Total[c]
Volume, ft^3	20,000	20,000	40,000
Total MFP, Ci[d]	6,000	20,000	30,000
^{90}Sr, Ci	1,000	40	1,000
^{106}Ru, Ci	1	7	8
^{137}Cs, Ci	1,000	40	1,000
^{60}Co, Ci	--	20,000	20,000
^{239}Pu, g	--	<500	<500

(a) Currently the distribution of waste plutonium stored on the Hanford site is 40% in tanks, 39% in solid sites and 21% in liquid disposal sites. The total amount of plutonium in these sites is estimated to be 940 kg ± 30%. Although to retrieve essentially all of the plutonium is technically feasible, it may not be economically justifiable.
(b) The estimated inventories (or concentrations) of radionuclides are reported to one significant figure to reflect the uncertainty in the data.
(c) Totals do not necessarily equal the sum of individual contributions because of rounding of the data.
(d) Curies shown are decayed to September 30, 1973.

APPENDIX II.1-C, Part 7

Gaseous Radioactivity Material Releases

TABLE II.1-C-26

SUMMARY OF RADIONUCLIDES IN GASEOUS WASTE
DISCHARGED FROM 200 AREA FACILITIES DURING 1972

291-A-1
Purex Process

Volume 6.32×10^{10} (ft^3)	Alpha*	Beta	^{131}I
Total Release (Ci)	3×10^{-3}	0.4	0.2
Avg. Release Rate (Ci/day)	8×10^{-6}	1×10^{-3}	8×10^{-4}
Max. Release Rate (Ci/day)	4×10^{-5}	2×10^{-3}	2×10^{-3}
Avg. Concentration (μCi/cc)	1×10^{-12}	2×10^{-10}	1×10^{-10}

*As Pu

296-A-1
Purex N and Q Cells
and PR Room

Volume 3.69×10^{9} (ft^3)		
Total Release (Ci)	1×10^{-3}	4×10^{-3}
Avg. Release Rate (Ci/day)	3×10^{-6}	1×10^{-5}
Max. Release Rate (Ci/day)	2×10^{-5}	2×10^{-5}
Avg. Concentration (μCi/cc)	2×10^{-13}	4×10^{-11}

*As Pu

296-A-2
Purex West Sample
Gallery Hoods

Volume 2.27×10^{9} (ft^3)		
Total Release (Ci)	3×10^{-6}	2×10^{-4}
Avg. Release Rate (Ci/day)	8×10^{-9}	5×10^{-7}
Max. Release Rate (Ci/day)	4×10^{-8}	9×10^{-7}
Avg. Concentration (μCi/cc)	5×10^{-14}	3×10^{-11}

*As Pu

296-A-3
Purex East Sample
Gallery Hoods

Volume 2.37×10^{9} (ft^3)		
Total Release (Ci)	3×10^{-6}	4×10^{-5}
Avg. Release Rate (Ci/day)	8×10^{-9}	1×10^{-7}
Max. Release Rate (Ci/day)	7×10^{-8}	3×10^{-7}
Avg. Concentration (μCi/cc)	4×10^{-14}	6×10^{-13}

*As Pu

296-A-5
Purex Lab Hoods and
Glove Boxes

Volume 1.32×10^{10} (ft^3)		
Total Release (Ci)	2×10^{-5}	3×10^{-4}
Avg. Release Rate (Ci/day)	5×10^{-8}	8×10^{-7}
Max. Release Rate (Ci/day)	1×10^{-7}	1×10^{-6}
Avg. Concentration (μCi/cc)	5×10^{-14}	8×10^{-13}

*As Pu

296-A-6
Purex East Sample
Gallery and U Cell

Volume 6.85×10^{9} (ft^3)		
Total Release (Ci)	6×10^{-6}	2×10^{-3}
Avg. Release Rate (Ci/day)	2×10^{-8}	6×10^{-6}
Max. Release Rate (Ci/day)	7×10^{-8}	3×10^{-5}
Avg. Concentration (μCi/cc)	3×10^{-14}	1×10^{-11}

*As Pu

TABLE II.1-C-26 (Continued)

296-A-7 Purex West Sample Gallery and R Cell Volume 1.05 x 10^{10} (ft^3)	Alpha*	Beta	^{131}I
Total Release (Ci)	3 x 10^{-5}	0.1	
Avg. Release Rate (Ci/day)	8 x 10^{-8}	4 x 10^{-4}	
Max. Release Rate (Ci/day)	3 x 10^{-7}	4 x 10^{-3}	
Avg. Concentration (μCi/cc)	1 x 10^{-13}	5 x 10^{-12}	
*As Pu			
296-A-8 Purex P & O Gallery (White Room) Volume 8.96 x 10^9 (ft^3)			
Total Release (Ci)	5 x 10^{-6}	4 x 10^{-4}	
Avg. Release Rate (Ci/day)	1 x 10^{-8}	1 x 10^{-6}	
Max. Release Rate (Ci/day)	7 x 10^{-8}	1 x 10^{-5}	
Avg. Concentration (μCi/cc)	2 x 10^{-14}	2 x 10^{-12}	
*As Pu			
296-A-10 Purex Burial Tunnel No. 2 Volume 5.16 x 10^9 (ft^3)			
Total Release (Ci)	3 x 10^{-5}	4 x 10^{-4}	
Avg. Release Rate (Ci/day)	8 x 10^{-8}	1 x 10^{-6}.	
Max. Release Rate (Ci/day)	8 x 10^{-7}	7 x 10^{-6}	
Avg. Concentration (μCi/cc)	2 x 10^{-13}	3 x 10^{-12}	
*As Pu			
296-A-12 AR Vault Vessel Vent Volume 1.74 x 10^8 (ft^3)			
Total Release (Ci)	3 x 10^{-7}	1 x 10^{-4}	2 x 10^{-3}
Avg. Release Rate (Ci/day)	9 x 10^{-10}	4 x 10^{-7}	8 x 10^{-6}
Max. Release Rate (Ci/day)	2 x 10^{-9}	2 x 10^{-6}	4 x 10^{-5}
Avg. Concentration (μCi/cc)	7 x 10^{-14}	3 x 10^{-11}	5 x 10^{-10}
*As Pu			
296-A-13 AR Vault and Cell Volume 1.08 x 10^{10} (ft^3)			
Total Release (Ci)	2 x 10^{-5}	3 x 10^{-3}	2 x 10^{-3}
Avg. Release Rate (Ci/day)	4 x 10^{-8}	7 x 10^{-6}	8 x 10^{-6}
Max. Release Rate (Ci/day)	8 x 10^{-8}	5 x 10^{-5}	4 x 10^{-5}
Avg. Concentration (μCi/cc)	5 x 10^{-14}	9 x 10^{-12}	8 x 10^{-12}
*As Pu			
296-A-14 293-A Bldg. Volume 3.16 x 10^9 (ft^3)			
Total Release (Ci)	3 x 10^{-6}	3 x 10^{-5}	
Avg. Release Rate (Ci/day)	8 x 10^{-9}	9 x 10^{-8}	
Max. Release Rate (Ci/day)	7 x 10^{-8}	6 x 10^{-7}	
Avg. Concentration (μCi/cc)	3 x 10^{-14}	4 x 10^{-13}	
*As Pu			

296-A-17
241-A, AX and AY
Tank Farm Vent

	Alpha*	Beta	^{131}I
Volume 2.64×10^{9} (ft^3)			
Total Release (Ci)	5×10^{-6}	3×10^{-4}	
Avg. Release Rate (Ci/day)	1×10^{-8}	9×10^{-7}	
Max. Release Rate (Ci/day)	1×10^{-7}	5×10^{-6}	
Avg. Concentration (μCi/cc)	6×10^{-14}	4×10^{-13}	

*As Pu

296-A-18
101-AY Tank Annulus

	Alpha*	Beta	^{131}I
Volume 1.26×10^{9} (ft^3)			
Total Release (Ci)	1×10^{-7}	4×10^{-6}	
Avg. Release Rate (Ci/day)	3×10^{-10}	1×10^{-8}	
Max. Release Rate (Ci/day)	5×10^{-10}	2×10^{-8}	
Avg. Concentration (μCi/cc)	3×10^{-15}	1×10^{-13}	

*As Pu

296-A-19
102-AY Tank Annulus

	Alpha*	Beta	^{131}I
Volume 1.26×10^{9} (ft^3)			
Total Release (Ci)	2×10^{-7}	1×10^{-5}	
Avg. Release Rate (Ci/day)	7×10^{-10}	3×10^{-8}	
Max. Release Rate (Ci/day)	2×10^{-9}	2×10^{-7}	
Avg. Concentration (μCi/cc)	7×10^{-15}	3×10^{-13}	

*As Pu

291-B-1
B Plant Process

	Alpha*	Beta	^{131}I
Volume 2.90×10^{10} (ft^3)			
Total Release (Ci)	1×10^{-5}	0.2	
Avg. Release Rate (Ci/day)	1×10^{-7}	4×10^{-4}	
Max. Release Rate (Ci/day)	2×10^{-7}	2×10^{-3}	
Avg. Concentration (μCi/cc)	5×10^{-14}	2×10^{-10}	

*As Pu

296-B-2
ITS No. 1

	Alpha*	Beta	^{131}I
Volume 1.84×10^{9} (ft^3)			
Total Release (Ci)	4×10^{-6}	1×10^{-2}	
Avg. Release Rate (Ci/day)	1×10^{-8}	4×10^{-5}	
Max. Release Rate (Ci/day)	2×10^{-8}	3×10^{-4}	
Avg. Concentration (μCi/cc)	8×10^{-14}	3×10^{-10}	

*As Pu

296-B-3
ITS No. 2

	Alpha*	Beta	^{131}I
Volume 2.11×10^{8} (ft^3)			
Total Release (Ci)	8×10^{-7}	6×10^{-3}	
Avg. Release Rate (Ci/day)	2×10^{-9}	2×10^{-5}	
Max. Release Rate (Ci/day)	1×10^{-8}	8×10^{-5}	
Avg. Concentration (μCi/cc)	1×10^{-13}	1×10^{-11}	

*As Pu

TABLE II.1-C-26 (Continued)

291-C-1 Semiworks Process and Cells Volume 1.05 x 10^{10} (ft^3)	Alpha*	Beta	^{131}I
Total Release (Ci)	7 x 10^{-6}	2 x 10^{-3}	
Avg. Release Rate (Ci/day)	2 x 10^{-8}	4 x 10^{-6}	
Max. Release Rate (Ci/day)	4 x 10^{-8}	3 x 10^{-5}	
Avg. Concentration (μCi/cc)	2 x 10^{-14}	5 x 10^{-12}	
*As Pu			
296-C-2 Semiworks A and C Sample Galleries Volume 4.22 x 10^9 (ft^3)			
Total Release (Ci)	6 x 10^{-7}	1 x 10^{-5}	
Avg. Release Rate (Ci/day)	2 x 10^{-9}	3 x 10^{-8}	
Max. Release Rate (Ci/day)	5 x 10^{-9}	1 x 10^{-7}	
Avg. Concentration (μCi/cc)	5 x 10^{-15}	1 x 10^{-13}	
*As Pu			
296-C-5 CR Vault Cell and Vessel Vent Volume 1.84 x 10^9 (ft^3)			
Total Release (Ci)	2 x 10^{-6}	2 x 10^{-4}	
Avg. Release Rate (Ci/day)	5 x 10^{-9}	5 x 10^{-7}	
Max. Release Rate (Ci/day)	1 x 10^{-8}	4 x 10^{-6}	
Avg. Concentration (μCi/cc)	4 x 10^{-14}	3 x 10^{-12}	
*As Pu			
296-P-1 (296-B-11) BX Tank Farm Volume 3.69 x 10^9 (ft^3)			
Total Release (Ci)	2 x 10^{-7}	2 x 10^{-5}	
Avg. Release Rate (Ci/day)	5 x 10^{-10}	4 x 10^{-8}	
Max. Release Rate (Ci/day)	8 x 10^{-10}	3 x 10^{-7}	
Avg. Concentration (μCi/cc)	2 x 10^{-15}	1 x 10^{-13}	
*As Pu			
296-P-2 (296-B-9) ITS Bottoms Tanks Volume 2.59 x 10^9 (ft^3)			
Total Release (Ci)	4 x 10^{-6}	5 x 10^{-4}	
Avg. Release Rate (Ci/day)	1 x 10^{-8}	1 x 10^{-6}	
Max. Release Rate (Ci/day)	3 x 10^{-8}	6 x 10^{-6}	
Avg. Concentration (μCi/cc)	5 x 10^{-14}	7 x 10^{-12}	
*As Pu			
296-P-3 (296-B-6) ITS Bottoms Tanks Volume 3.69 x 10^9 (ft^3)			
Total Release (Ci)	5 x 10^{-6}	2 x 10^{-3}	
Avg. Release Rate (Ci/day)	1 x 10^{-8}	5 x 10^{-6}	
Max. Release Rate (Ci/day)	2 x 10^{-8}	3 x 10^{-5}	
Avg. Concentration (μCi/cc)	4 x 10^{-14}	2 x 10^{-11}	
*As Pu			

TABLE II.1-C-26 (Continued)

	Alpha*	Beta	^{131}I
296-P-4 (296-B-8) ITS Bottoms Tanks			
Volume 7.91×10^7 (ft^3)			
Total Release (Ci)	5×10^{-8}	2×10^{-5}	
Avg. Release Rate (Ci/day)	1×10^{-10}	5×10^{-8}	
Max. Release Rate (Ci/day)	3×10^{-10}	3×10^{-7}	
Avg. Concentration (μCi/cc)	2×10^{-14}	8×10^{-12}	
*As Pu			
296-P-5 (296-C-6) Tanks 105 and 106-C			
Volume 6.78×10^7 (ft^3)			
Total Release (Ci)	8×10^{-7}	4×10^{-5}	
Avg. Release Rate (Ci/day)	2×10^{-9}	1×10^{-7}	
Max. Release Rate (Ci/day)	9×10^{-9}	4×10^{-7}	
Avg. Concentration (μCi/cc)	4×10^{-13}	2×10^{-11}	
*As Pu			
296-P-8 (296-T-4) 242-TX Evaporator Bottoms Tanks			
Volume 3.16×10^9 (ft^3)			
Total Release (Ci)	4×10^{-6}	1×10^{-4}	
Avg. Release Rate (Ci/day)	2×10^{-8}	6×10^{-7}	
Max. Release Rate (Ci/day)	3×10^{-8}	1×10^{-6}	
Avg. Concentration (μCi/cc)	5×10^{-14}	2×10^{-13}	
*As Pu			
296-P-10 (296-T-10) 242-TX Evaporator Bottoms Tanks			
Volume 3.69×10^9 (ft^3)			
Total Release (Ci)	5×10^{-6}	1×10^{-3}	
Avg. Release Rate (Ci/day)	1×10^{-8}	3×10^{-6}	
Max. Release Rate (Ci/day)	3×10^{-8}	1×10^{-5}	
Avg. Concentration (μCi/cc)	5×10^{-14}	1×10^{-11}	
*As Pu			
296-P-11 (296-T-9) 242-TX Evaporator Bottoms Tanks			
Volume 7.91×10^7 (ft^3)			
Total Release (Ci)	9×10^{-8}	2×10^{-5}	
Avg. Release Rate (Ci/day)	3×10^{-10}	5×10^{-8}	
Max. Release Rate (Ci/day)	5×10^{-10}	1×10^{-7}	
Avg. Concentration (μCi/cc)	4×10^{-14}	8×10^{-12}	
*As Pu			
296-P-12 (296-T-11) 242-TX Evaporator Bottoms Tanks			
Volume 3.69×10^9 (ft^3)			
Total Release (Ci)	6×10^{-6}	6×10^{-4}	
Avg. Release Rate (Ci/day)	2×10^{-8}	2×10^{-6}	
Max. Release Rate (Ci/day)	5×10^{-8}	6×10^{-6}	
Avg. Concentration (μCi/cc)	6×10^{-14}	5×10^{-12}	
*As Pu			

TABLE II.1-C-26 (Continued)

291-S-1
Redox Process Vessels

Volume 2.06×10^{10} (ft^3)	Alpha*	Beta	^{131}I
Total Release (Ci)	5×10^{-5}	9×10^{-4}	
Avg. Release Rate (Ci/day)	1×10^{-7}	2×10^{-6}	
Max. Release Rate (Ci/day)	2×10^{-7}	4×10^{-6}	
Avg. Concentration (µCi/cc)	9×10^{-14}	2×10^{-12}	

*As Pu

296-S-1
Redox South Sample Gallery

Volume 1.84×10^{9} (ft^3)			
Total Release (Ci)	7×10^{-7}	1×10^{-5}	
Avg. Release Rate (Ci/day)	2×10^{-9}	3×10^{-8}	
Max. Release Rate (Ci/day)	8×10^{-9}	9×10^{-8}	
Avg. Concentration (µCi/cc)	1×10^{-14}	2×10^{-13}	

*As Pu

296-S-2
Redox North Sample Gallery and Hoods

Volume 1.84×10^{9} (ft^3)			
Total Release (Ci)	3×10^{-7}	1×10^{-4}	
Avg. Release Rate (Ci/day)	8×10^{-10}	3×10^{-7}	
Max. Release Rate (Ci/day)	1×10^{-9}	3×10^{-6}	
Avg. Concentration (µCi/cc)	5×10^{-15}	2×10^{-12}	

*As Pu

296-S-4
Redox Regulated Shop and Tool Room and SWP Lobby

Volume 1.16×10^{9} (ft^3)			
Total Release (Ci)	7×10^{-7}	4×10^{-5}	
Avg. Release Rate (Ci/day)	2×10^{-9}	1×10^{-7}	
Max. Release Rate (Ci/day)	4×10^{-9}	2×10^{-7}	
Avg. Concentration (µCi/cc)	2×10^{-14}	1×10^{-12}	

*As Pu

296-S-5
Redox Product Removal Cage

Volume 9.49×10^{8} (ft^3)			
Total Release (Ci)	8×10^{-7}	6×10^{-6}	
Avg. Release Rate (Ci/day)	3×10^{-9}	2×10^{-8}	
Max. Release Rate (Ci/day)	5×10^{-9}	4×10^{-8}	
Avg. Concentration (µCi/cc)	3×10^{-14}	2×10^{-13}	

*As Pu

296-S-6
Redox Silo Sample Gallery

Volume 5.53×10^{9} (ft^3)			
Total Release (Ci)	4×10^{-6}	2×10^{-4}	
Avg. Release Rate (Ci/day)	1×10^{-8}	4×10^{-7}	
Max. Release Rate (Ci/day)	5×10^{-8}	3×10^{-6}	
Avg. Concentration (µCi/cc)	3×10^{-14}	1×10^{-12}	

*As Pu

TABLE II.1-C-26 (Continued)

296-S-7 Redox Product (233-S) Process Vessels and Greenhouse	Alpha*	Beta	^{131}I
Volume 4.06×10^{9} (ft^3)			
Total Release (Ci)	5×10^{-5}	2×10^{-4}	
Avg. Release Rate (Ci/day)	1×10^{-7}	6×10^{-7}	
Max. Release Rate (Ci/day)	4×10^{-7}	4×10^{-6}	
Avg. Concentration (μCi/cc)	4×10^{-13}	2×10^{-12}	
*As Pu			
296-S-13 222-S Laboratory			
Volume 3.64×10^{10} (ft^3)			
Total Release (Ci)	5×10^{-5}	4×10^{-2}	
Avg. Release Rate (Ci/day)	1×10^{-7}	1×10^{-4}	
Max. Release Rate (Ci/day)	5×10^{-7}	6×10^{-4}	
Avg. Concentration (μCi/cc)	5×10^{-14}	3×10^{-11}	
*As Pu			
296-S-14 241-SX Tank Farm Vent			
Volume 3.16×10^{8} (ft^3)			
Total Release (Ci)	4×10^{-6}	4×10^{-3}	
Avg. Release Rate (Ci/day)	1×10^{-8}	1×10^{-5}	
Max. Release Rate (Ci/day)	8×10^{-8}	4×10^{-5}	
Avg. Concentration (μCi/cc)	5×10^{-13}	5×10^{-10}	
*As Pu			
296-S-15 241-SX Sludge Cooling			
Volume 5.27×10^{9} (ft^3)			
Total Release (Ci)	1×10^{-5}	1×10^{-4}	
Avg. Release Rate (Ci/day)	3×10^{-8}	4×10^{-7}	
Max. Release Rate (Ci/day)	1×10^{-7}	1×10^{-6}	
Avg. Concentration (μCi/cc)	8×10^{-14}	1×10^{-12}	
*As Pu			
296-S-16 222 S Lab Waste Tanks and Vault			
Volume 5.96×10^{7} (ft^3)			
Total Release (Ci)	1×10^{-6}	9×10^{-5}	
Avg. Release Rate (Ci/day)	3×10^{-9}	3×10^{-7}	
Max. Release Rate (Ci/day)	8×10^{-9}	9×10^{-7}	
Avg. Concentration (μCi/cc)	6×10^{-13}	6×10^{-11}	
*As Pu			
291-T-1 T Plant			
Volume 2.11×10^{10} (ft^3)			
Total Release (Ci)	2×10^{-4}	4×10^{-2}	
Avg. Release Rate (Ci/day)	7×10^{-7}	1×10^{-4}	
Max. Release Rate (Ci/day)	3×10^{-6}	5×10^{-4}	
Avg. Concentration (μCi/cc)	4×10^{-13}	6×10^{-11}	
*As Pu			

TABLE II.1-C-26 (Continued)

296-T-1 242-T Evaporator Hot Cells	Alpha*	Beta	^{131}I
Volume 4.22×10^{8} (ft^3)			
Total Release (Ci)	1×10^{-6}	3×10^{-3}	
Avg. Release Rate (Ci/day)	3×10^{-9}	9×10^{-6}	
Max. Release Rate (Ci/day)	7×10^{-9}	3×10^{-5}	
Avg. Concentration (μCi/cc)	8×10^{-14}	3×10^{-10}	
*As Pu			
296-T-2 242-T Evaporator Cold Cells			
Volume 4.48×10^{8} (ft^3)			
Total Release (Ci)	1×10^{-6}	2×10^{-4}	
Avg. Release Rate (Ci/day)	3×10^{-9}	5×10^{-7}	
Max. Release Rate (Ci/day)	8×10^{-9}	1×10^{-6}	
Avg. Concentration (μCi/cc)	9×10^{-14}	1×10^{-11}	
*As Pu			
296-T-3 242-T Evaporator Vessel Vent			
Volume 1.05×10^{8} (ft^3)			
Total Release (Ci)	7×10^{-7}	1×10^{-3}	
Avg. Release Rate (Ci/day)	2×10^{-9}	3×10^{-6}	
Max. Release Rate (Ci/day)	1×10^{-8}	1×10^{-5}	
Avg. Concentration (μCi/cc)	2×10^{-13}	4×10^{-10}	
*As Pu			
296-T-13 T Plant			
Volume 1.43×10^{10} (ft^3)			
Total Release (Ci)	1×10^{-5}	4×10^{-4}	
Avg. Release Rate (Ci/day)	6×10^{-8}	2×10^{-6}	
Max. Release Rate (Ci/day)	1×10^{-7}	5×10^{-6}	
Avg. Concentration (μCi/cc)	3×10^{-14}	1×10^{-12}	
*As Pu			
291-U-1 U Plant			
Volume 7.38×10^{9} (ft^3)			
Total Release (Ci)	1×10^{-5}	1×10^{-3}	
Avg. Release Rate (Ci/day)	4×10^{-8}	3×10^{-6}	
Max. Release Rate (Ci/day)	9×10^{-8}	5×10^{-6}	
Avg. Concentration (μCi/cc)	6×10^{-14}	5×10^{-12}	
*As Pu			
296-U-2 Uranium Oxide 224-UA Filters			
Volume 3.81×10^{8} (ft^3)			
Total Release (Ci)	8×10^{-5}	2×10^{-4}	
Avg. Release Rate (Ci/day)	4×10^{-7}	2×10^{-6}	
Max. Release Rate (Ci/day)	1×10^{-6}	2×10^{-6}	
Avg. Concentration (μCi/cc)	8×10^{-12}	2×10^{-11}	
*As U			

TABLE II.1-C-26 (Continued)

296-U-4 Uranium Oxide Nitric Acid Absorber Off-gas	Alpha*	Beta	^{131}I
Volume 7.66 x 10^8 (ft^3)			
Total Release (Ci)	7 x 10^{-6}	5 x 10^{-3}	
Avg. Release Rate (Ci/day)	2 x 10^{-8}	2 x 10^{-5}	
Max. Release Rate (Ci/day)	7 x 10^{-8}	5 x 10^{-5}	
Avg. Concentration (μCi/cc)	3 x 10^{-13}	2 x 10^{-10}	
*As U			
296-U-5 Uranium Oxide 224-U F Cell			
Volume 2.29 x 10^8 (ft^3)			
Total Release (Ci)	2 x 10^{-6}	7 x 10^{-4}	
Avg. Release Rate (Ci/day)	7 x 10^{-9}	3 x 10^{-6}	
Max. Release Rate (Ci/day)	1 x 10^{-8}	4 x 10^{-6}	
Avg. Concentration (μCi/cc)	3 x 10^{-13}	1 x 10^{-10}	
*As U			
296-U-10 271-U PU Storage			
Volume 5.32 x 10^9 (ft^3)			
Total Release (Ci)	4 x 10^{-7}	7 x 10^{-6}	
Avg. Release Rate (Ci/day)	3 x 10^{-9}	6 x 10^{-8}	
Max. Release Rate (Ci/day)	2 x 10^{-9}	6 x 10^{-8}	
Avg. Concentration (μCi/cc)	3 x 10^{-15}	5 x 10^{-14}	
*As Pu			
291-Z-1 ZPlant Process and Ventilation			
Volume 1.26 x 10^{11} (ft^3)			
Total Release (Ci)	3 x 10^{-4}	2 x 10^{-3}	
Avg. Release Rate (Ci/day)	8 x 10^{-7}	5 x 10^{-6}	
Max. Release Rate (Ci/day)	3 x 10^{-6}	2 x 10^{-5}	
Avg. Concentration (μCi/cc)	8 x 10^{-14}	6 x 10^{-13}	
*As Pu			
296-Z-3 241-Z Vault			
Volume 1.32 x 10^{10} (ft^3)			
Total Release (Ci)	4 x 10^{-6}	5 x 10^{-6}	
Avg. Release Rate (Ci/day)	2 x 10^{-8}	2 x 10^{-8}	
Max. Release Rate (Ci/day)	2 x 10^{-8}	2 x 10^{-8}	
Avg. Concentration (μCi/cc)	1 x 10^{-14}	1 x 10^{-14}	
*As Pu			
209-E Critical Mass Lab			
Volume 1.21 x 10^9 (ft^3)			
Total Release (Ci)	<2 x 10^{-7}		
Avg. Release Rate (Ci/wk)	<3 x 10^{-9}		
Max. Release Rate (Ci/wk)	<2 x 10^{-8}		
Avg. Concentration (μCi/cc)	<8 x 10^{-15}		
*As Pu			
231-Z Plutonium Metallurgy Lab			
Volume 5.19 x 10^9 (ft^3)			
Total Release (Ci)	1 x 10^{-5}		
Avg. Release Rate (Ci/wk)	2 x 10^{-7}		
Max. Release Rate (Ci/day)	2 x 10^{-6}		
Avg. Concentration (μCi/cc)	8 x 10^{-14}		
*As Pu			

APPENDIX II.1-C, Part 8

Unplanned Releases

TABLE II.1-C-27

200 AREAS, UNPLANNED RELEASES

Date	Location	Description	Approximate Amounts of Radionuclides
11-73	241-S Tank Farm 102-S Tank	Approximately 8,660 gallons of radioactive waste solution was pumped out of a 12-inch riser on to the adjacent ground and covered an area approximately 50 x 200 feet. This was caused by an unplanned blockage in the riser. The spill area was immediately covered with a temporary layer of earth to provide shielding and prevent airborne contamination. Final cleanup operations excavated all of the contaminated soil for subsequent disposal in a designated contaminated burial trench.	1,000 Ci ^{137}Cs 1 Ci ^{134}Cs 1 Ci ^{60}Co
8-72	221-B, R-13 Utility Pit	Excavation of an unencased line (from Tank 18-1, 221-B Building to 154-BX diversion box) near the utility pit at R-13 disclosed a process waste leak. Radiation measurements taken at bottom of the pit read 15 rad/hr within 2 in. of the source.	20 Ci ^{137}Cs
2-72	224-T Building southeast side	During remodeling of 224-T Building for Pu storage, gross alpha contamination was found in soil on back side of building. The 224-T Building was originally constructed with vent lines from process tanks entering tile piping at ground level to rear of building. The jointed tile piping went to a common tile header which fed into 221-T Building cells. During the years of process operation, alpha-ladened moisture seeped through pipe joints and grossly contaminated the subsoil. Excavations of area showed soil contamination below the surface of an area 50 ft long by 12 ft wide by 12 ft deep. A total of 139 drums of soil were removed from the zone containing approximately 70 g of plutonium. The zone is marked for underground contamination which remains below the header pipe. (It is believed a similar contaminated condition exists behind 224-B Building in 200-East Area.)	10 g ^{239}Pu Residual
4-71	216-Z-18 waste line near 236-Z	The 216-Z-18 crib line from 234-5 complex broke at location approximately 6 ft south and 12 ft west of southwest corner of 236-Z Building. An excavation 25 ft long by 6 ft wide by 7 ft deep uncovered gross alpha contamination in soil to greater than 6 million dis/min/100 cm^2 of surface. Approximately one hundred 55-gal barrels of contaminated soil were removed and buried in 200-W Area Pu "storage for recovery" burial ground. Much contamination still remains under 6 ft of clean soil.	10 g ^{239}Pu
3-71	Near southwest corner of 241-C Tank Farm	Process transfer line No. 812 from AR Vault to 241-C Tank Farm was found leaking near southwest corner of that farm. At that location the line is 8 ft deep. Contaminated soil zone was estimated at 1300 ft^3. Test wells driven into the ground indicated the contamination did not extend below a depth of 20 ft.	30,000 Ci ^{137}Cs
3-22-70	221-B to 216-B-3 (B Pond)	Decontamination of operating gallery, following process solution flow reversal from storage vessel.	50 Ci ^{90}Sr
11-69	Near 241-C-152 diversion box. Liquid radioactive waste transfer line break	A leak in the line from Tank 105-C to B Plant was found December 19, 1969. Volume which leaked to ground was estimated at 2600 gal. The contaminated soil was covered with clean gravel.	10,000 Ci ^{137}Cs 300 Ci ^{144}Ce 100 Ci ^{106}Ru 300 Ci $^{95}ZrNb$ 100 Ci ^{134}Cs
10-69	Near 241-CR-151 diversion box. Liquid radioactive waste transfer line break	A leak in the line from Purex Plant to 102-C tank was found October 19, 1969. Volume which leaked to ground was estimated at 36,000 gal. Contamination was covered with clean gravel.	400 Ci ^{90}Sr 700 Ci ^{137}Cs 400 Ci ^{144}Ce 1,000 Ci $^{95}ZrNb$ 1,000 Ci ^{103}Ru
1-69	233-S	Plutonium-contaminated water backed up in 233-S Filter House drain line and overflowed into a low spot in the ground directly north of 233-S Filter House. An area of 150 yd^2 was affected. Twenty-eight yards of clean gravel were spread over the spill.	0.1 g ^{239}Pu

TABLE II.1-C-27 (Continued)

Date	Location	Description	Approximate Amounts of Radionuclides
9-68	153-TX diversion box	Ground and road contamination along Camden Av. and adjacent ground surfaces resulted from two plumes of airborne contamination that floated northeast and southeast from 153-TX diversion box depositing ^{90}Sr over an area running 250 yd north and south along Camden and extending from 75 to 100 yd east of Camden. Particles up to 700 mrad/hr were found. Road contamination was covered with a new tar mat, sides of roads were "fixed" with tar, and the field to the east of Camden Av. was turned under to cover the particulate material.	1 Ci ^{90}Sr
1-68	Near 241-B-153	A leak in the transfer line from 9-2 tank in 221-B Plant to the 110-B underground storage tank was found near 241-B-153 diversion box on January 4, 1968. The volume which leaked to the ground was estimated at 5400 gal. The contaminated ground was covered with clean gravel.	5,000 Ci ^{144}Ce 300 Ci ^{106}Ru 800 Ci $^{95}ZrNb$
5-66	23rd and Camden Ave.	Liquid waste solution spilled from a broken underground line on southeast corner of 23rd and Camden Ave. The liquid surfaced and ran across the road to west side. All ground surface contamination was removed to a depth of 3 ft and buried in the 200-W burial grounds. The remaining radioactivity was covered to ground level with 3 ft of clean soil.	10 Ci Fission Products
9-30-60	202-A	During jumper testing on 241-A-151 Diversion Box, contamination was spread downwind to the south and outside the 200-E Area perimeter fence, a distance of about 1 mile. Radiation levels near the diversion box were 1 to 3 rad/hr, and just outside the exclusion area fence, general contamination was up to 3000 counts/min. Particulate contamination was about 50 particles per 100 ft^2 just outside the exclusion area and dropped to less than 5 particles per 100 ft^2 1 mile south of the diversion box. Ground surface contamination was removed or stabilized.	0.1 Ci
Early 1960	B-C Cribs outer area	Early in 1960 animal burrows were observed in residue salts in bottom of B-C liquid waste trenches. Radioactive feces from coyotes and rabbits were subsequently spread over surrounding sagebrush-covered desert land to east, south and west of trenches. The bulk of radioactivity remaining is fixed in rabbit droppings scattered over approximately 4 square miles of ground surface.	7 Ci ^{137}Cs 30 Ci ^{90}Sr
3-57	221-U Building	Reclaimed acid spilled onto ground at northeast end of 221-U Building, contaminating an area 65 ft by 90 ft. The spill was covered with 3 in. of sand and gravel.	1 Ci Fission Products
10-55	Near 241-BX-153 and 241-BX-155 Ground Contamination	A spill that occurred during pressure testing of lines and jumpers in the 155-BX diversion box caused ground contamination to a maximum dose rate of 22.6 rad/hr at surface. Affected area is approximately 200 ft^2. It was covered with clean soil.	10 Ci Fission Products
1954-55	241-B-153	Contamination spread associated with work being done in the 153-B diversion box during 1954 and 1955 caused a general buildup of contamination. An area 50 ft by 100 ft is marked as a radiation zone. The contamination was covered with clean gravel.	1 Ci Fission Products
1954	241-B-152	An incident which occurred during the spring of 1954 while performing diversion box work contaminated an area approximately 50 ft^2. A portion of the contamination was removed and buried. The remainder was covered with several inches of clean fill dirt.	1 Ci Fission Products
1954	Leak in process line from 105-TX to 118-TX	Leakage of first cycle waste was discovered in 1954 with maximum dose rates of 4.5 R/hr observed at 4 ft above surface of spill. An area approximately 100 ft by 125 ft was covered with soil.	10 Ci Fission Products

TABLE II.1-C-27 (Continued)

Date	Location	Description	Approximate Amounts of Radionuclides
1954	216-S-207 Redox retention basin	Basin became highly contaminated from coil leaks in 202-S Building. Its use was discontinued in 1954. Basin concrete surfaces were subsequently covered with soil.	10 Ci Fission Products
1-2-54	Redox	During Ru oxidation and scrubbing operations, the caustic recirculation system was not functioning properly and about 260 Ci of radio-Ru were released to the environs via the ventilation stack. The wind was blowing in a general northeasterly direction and particulate radio-Ru was deposited on vegetation and roads extending beyond the Hanford perimeter. Individual high radiation measurements of particles were: 7.5 rad/hr near the Redox stack, 400 mrad/hr on the road northeast of the stack, 100 mrad/hr down to 50 mrad/hr between 200-W and 200-E Area and diminishing to 20 mrad/hr northeast of the 200-E Area.	200 Ci ^{103}Ru 60 Ci ^{106}Ru
1953 to 1955	216-S-4 Culvert pipes (cooling water well)	241-S Tank Farm, 101 and 104 tank condensate and cooling water was piped from 241-S Tank Farm into two metal culvert pipes placed on end to a depth of 20 ft. Radioactivity accumulated at bottom of pipes.	1 Ci Fission Products
6-53	216-U-7 221-U Vessel vent blower pit French drain	An estimated 300 lb of uranium (UNH solution) overflowed into the 221-U Building vessel vent blower pit and then to ground through the French drain. (This is in the established radiation zone on southeast of 221-U Building near R-3 entrance.)	10 kg uranium
6-53	242-B to 207-B Waste Line	Five leaks in the line were discovered in June 1953. No determination of activity below ground surface was made at that date. The area was covered with about 2 in. of clean soil.	10 Ci Fission Products
3-53	241-ER-151 Catch tank leak	About 1700 gal of contaminated acid was lost to ground through a leaking catch tank. No ground surface contamination was detected.	10 Ci Fission Products
1951 to 1952	216-S-15 (110-S tank condenser cooling wastes)	A maximum dose rate of 10 rad/hr was observed at the surface of the receiving pond east of 241-S Tank Farm. It was covered with 2 ft of dirt.	1 Ci Fission Products
1951 to 1952	241-B-151	The area around the diversion box was contaminated as a result of diversion box work in the fall of 1951 and again in the summer of 1952. Most of the contamination was removed. That remaining was covered with approximately 1 ft of clean soil.	10 Ci Fission Products
1947	221-T, R-19 Waste line leak	A leak in underground metal waste line at southeast corner of 221-T Building in the spring of 1947 resulted in spread of an unknown amount of activity to ground. A maximum dose rate of 20 R/hr was detected. The area was subsequently covered with several feet of gravel.	10 Ci Fission Products
1946	221-B, R-3 Line leak	A leak during 1946 from an underground metal waste line south of 221-B Building resulted in spread of an unknown quantity of activity to an area 100 ft wide by 500 ft in length. A portion of the ground above the leak caved in but was subsequently backfilled with several feet of clean gravel. During subsequent construction activity the major portion of the radioactivity was excavated and removed to 200-E Dry Waste Burial Garden.	10 Ci Fission Products
1946	241-B-154 Ground Contamination	Metal waste solution was spread over the ground around the diversion box as a result of work associated with replacement of a leaky jumper in the box in 1946. The contamination was covered with approximately 1 ft of clean soil.	1 Ci Fission Products

Waste Storage Tank Leaks. Eighteen tank leaks have occurred through 1974. The number of each affected tank, the year of occurrence, the estimated volume of leakage in gallons, and the associated ^{137}Cs are shown below. The letter(s) after the number of each tank indicates their location by storage area, e.g., the letter "U" is the "U" tank farm, the letters "SX" mean the "SX" tank farm, etc. The tank farms can be found on the maps attached as Figure II.1-C-42.

The columns next to the list of eighteen tanks include the estimated volume of leakage from each tank and the associated ^{137}Cs in curies. ^{137}Cs leakage can be used to estimate the maximum amount of other radionuclides leaked.

	Tank	Year Leaked	Estimated Vol. of Leakage (Gallons)	Associated ^{137}Cs (1000 Ci)	Status
1.	104-U	1956	55,000	0.09	Diatomite added - Tank Isolated
2.	113-SX	1958	15,000	8	Diatomite added - Tank Isolated
3.	106-TY	1959	20,000	2	Diatomite added - Tank Isolated
4.	101-U	1959	30,000	20	Isolated
5.	105-TY	1960	35,000	4	Isolated
6.	108-SX	1962	2,400	20	Sludge Air Cooling
7.	105-A	1963	<5,000	--	Pumped to Residual Liquid Heel
8.	107-SX	1964	<5,000	--	Sludge Air Cooling
9.	109-SX	1965	<5,000	--	Sludge Air Cooling
10.	115-SX	1965	50,000	40	Sludge Air Cooling
11.	112-SX	1969	30,000	40	Sludge Air Cooling
12.	102-BX	1971	70,000	50	Diatomite added - Tank Isolated
13.	108-BY	1972	<5,000	--	Salt Well Pumping - Isolation in Progress
14.	103-BY	1973	<5,000	--	Salt Well and Isolation Program
15.	106-T	1973	115,000	40	Pumped to Residual Liquid Heel
16.	103-TY	1973	3,000	0.7	Salt Well Pumping - Isolation Initiated
17.	111-SX	1974	<2,000	2	Pumped to Residual Liquid Heel
18.	108-BX	1974	2,500	0.5	Pumped to Residual Liquid Heel

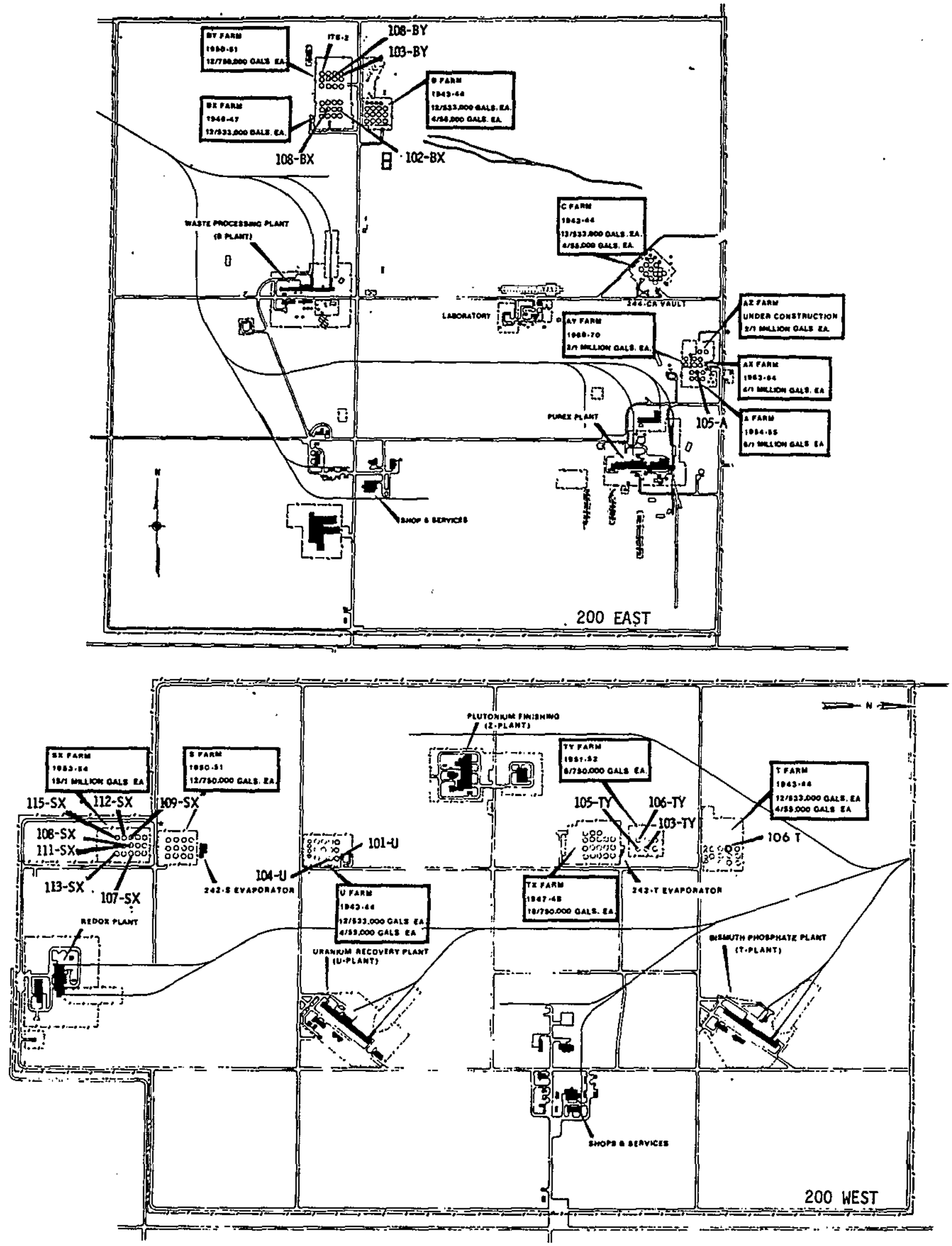

FIGURE II.1-C-47 200 AREAS TANK FARMS

APPENDIX II.1-D

LIQUID WASTE STREAMS TO THE COLUMBIA RIVER

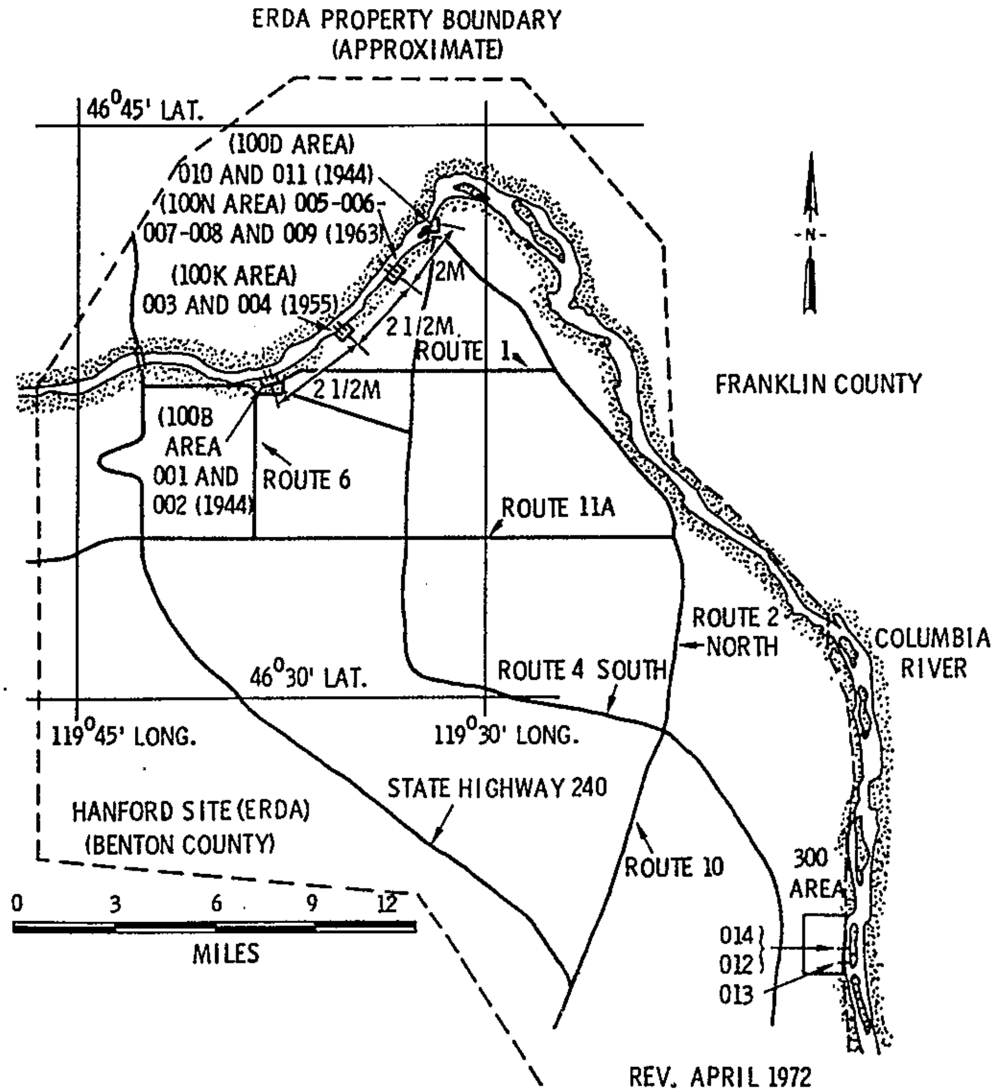

FIGURE II.1-D-1 EXISTING DISCHARGES INTO COLUMBIA RIVER

TABLE II.1-D-1

DESCRIPTION OF DISCHARGES

Area	Discharge[(a)] No.	Description
100-B/C	001	Inlet Screen Wash Water and Fish Return The 100-B river pumphouse serves 100-B Area, the chemical processing facilities (200 Areas) and other minor facilities totaling about 19 million gpd. Discharge line permit .001 covers untreated water used to dislodge and backflush material entrained on the river pump inlet screens (Figure II.1-D-2).
100-B/C	002	Process Drain Leakage and waste water from pumping operations in the 182-B building and overflow from the 183-B Başin raw water storage facility in 100-B Area are released to the river directly. These facilities are used in transporting water from river pumping structure to the 200 Areas (Figure II.1-D-3).
100-K	003	Inlet Screen Wash Water and Fish Return Untreated river water used to dislodge and backflush material entrained on the river pump inlet screens on the pumping structure serving 100-K Areas is released directly to the river (Figure II.1-D-4).
100-K	004	Process Drain Treated cooling water used for compressors and pumps and overflow drains from the filter basin are released directly to the river (Figure II.1-D-5).
100-N	005	Water Storage Tank Farm Overflow A 36-in. line containing the overflow from the 182-N tank empties into a concrete chute (Figure II.1-D-6). This discharge is a part of the approximately 200,000 gpm pumped by the 100-N river pumping facilities. It amounts to about 500 gpm of overflow from filtered and raw water storage tanks in the 182-N tank farm. A small amount of steam from the medium pressure steam system is included.
100-N	006	Overflow and Floor Drain Discharge Figure II.1-D-7 shows the discharge point from the 182-N building consisting of filtered water overflow and waste from floor drains into a 12-in. steel pipe to the river bank. This is also part of the 200,000 gpm pumped by the 100-N river pumping facilities.
100-N	00/	Inlet Screen Wash Water and Fish Return This discharge consists of untreated water used to dislodge and back flush material entrained on river pump inlet screens. The entrained material consists only of solid matter present in untreated Columbia River water (Figure II.1-D-8).
100-N	008	Turbine Condenser Cooling Water This process waste discharge is a part of the approximate 200,000 gpm pumped by the 100-N river pumping facilities . It consists of drive and generator turbine condenser cooling water and graphite cooling water discharged via a 66-in. line and concrete flume to the river bank (Figure II.1-D-9). During normal reactor operating periods the flows are about 65,000 gpm.

(a) Application for EPA discharge permit number is 071-OYC-3-000099 covering 14 discharges.

TABLE II.1-D-1 (Continued)

Area	Discharge[a] No.	Description
100-N	009	Dump Condenser Cooling Water This waste consists primarily of steam condenser cooling water discharged via a 102-in. line to the Columbia river channel (Figure II.1-D-10).
100-D/DR	010	Inlet Screen Wash Water and Fish Return Untreated water used to dislodge and backflush material entrained on the river pump inlet screens is returned to the river. The entrained material consists only of solid matter present in untreated Columbia River water. The pumping plant serves sanitary needs and process water to research facilities located in the 100-D Area (Figure II.1-D-11).
100-D/DR	011	Research Facility and Backwash Drain Treated process water used in 189-D and 183-D as coolant and wash water and in hydraulic test loops is returned to the river. The test loops are part of a research and development facility in support of N Reactor and other interests. Radioactive materials are not included in the test loops (Figure II.1-D-12).
300	013	331 Fish Pond Effluent This stream results from an AEC research effort in which experimental stocks of fish and other aquatic organisms are maintained in fresh or treated Columbia River water. Experiments involve the addition of small amounts of chemical or temperature increments. This discharge includes only raw water which is not chemically treated (Figure II.1-D-13).
300	012	Filter Backwash This stream, which results from the normal operation of the water treatment plant filter backwash, carries water treatment chemicals as well as silt back to the river. The small water treatment plant is a conventional design. Aluminum sulfate is added to river water, a proprietary polyacrylamide called "Separan" is added as a filter aid, and the water is chlorinated. The finished water is used for sanitary and process needs in the 300 Area (Figure II.1-D-14).
300	014	309 Drains This stream involves cooling water from air conditioning chillers and floor drains from the south basement service area in the 309 Building. The water is initially from the 300 Area drinking water system and no chemicals or other pollutants are added (Figure II.1-D-15).

(a) Application for EPA discharge permit number is 071-OYC-3-000099 covering 14 discharges.

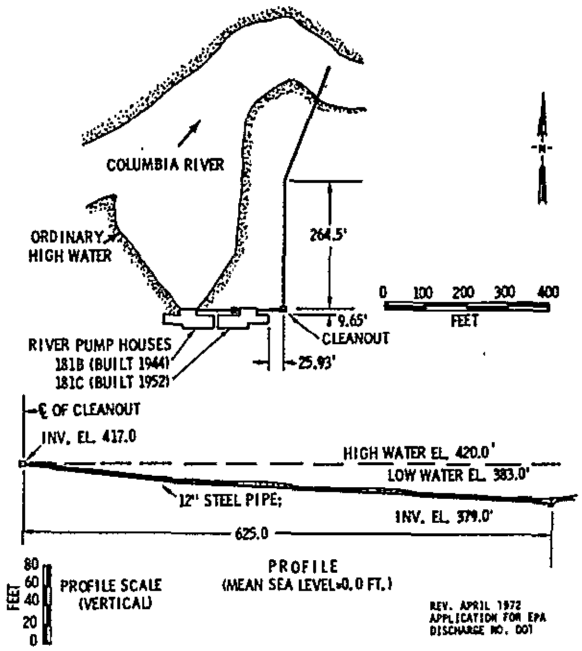

FIGURE II.1-D-2 INLET SCREEN WASH WATER, 100-B AREA

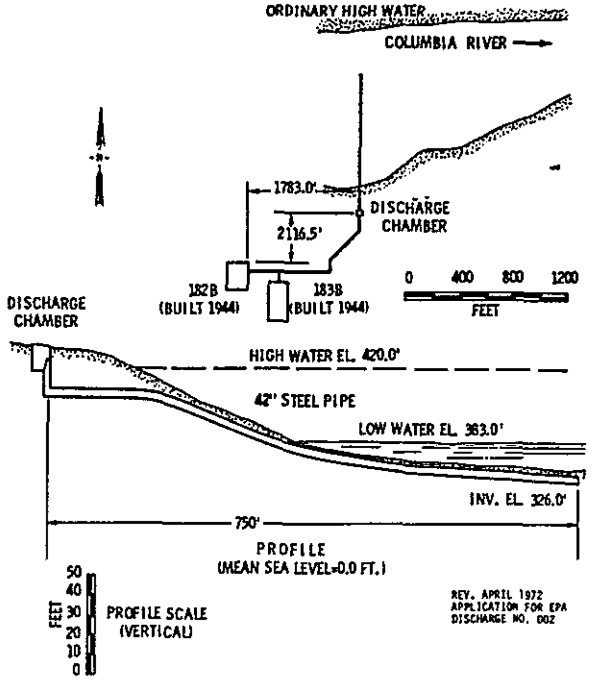

FIGURE II.1-D-3 PROCESS DRAIN, 100-B AREA

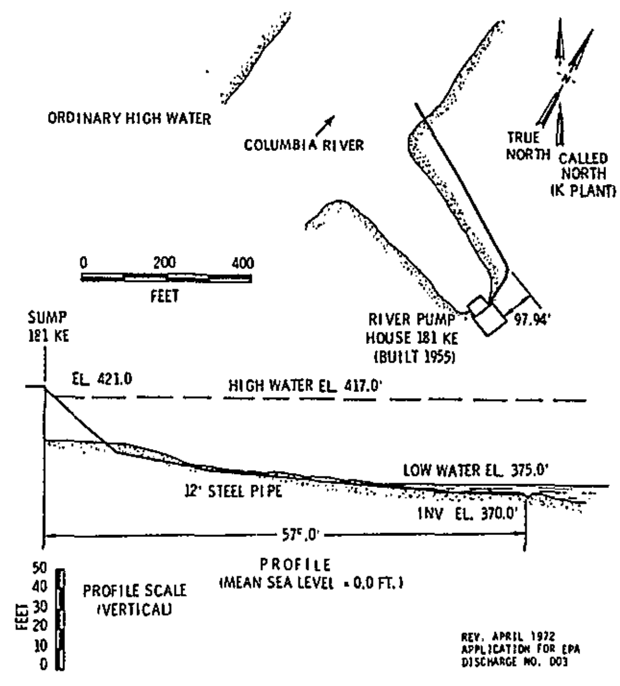

FIGURE II.1-D-4 INLET SCREEN WASH WATER, 100-K AREA

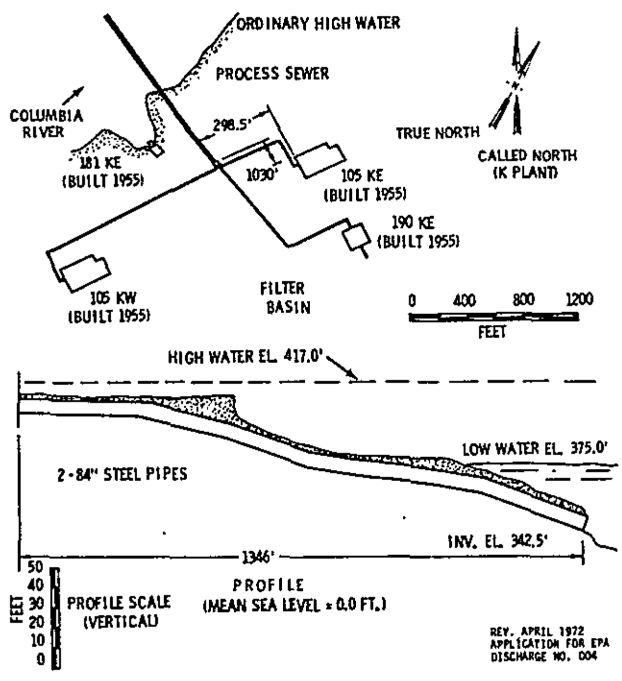

FIGURE II.1-D-5 PROCESS DRAIN, 100-K AREA

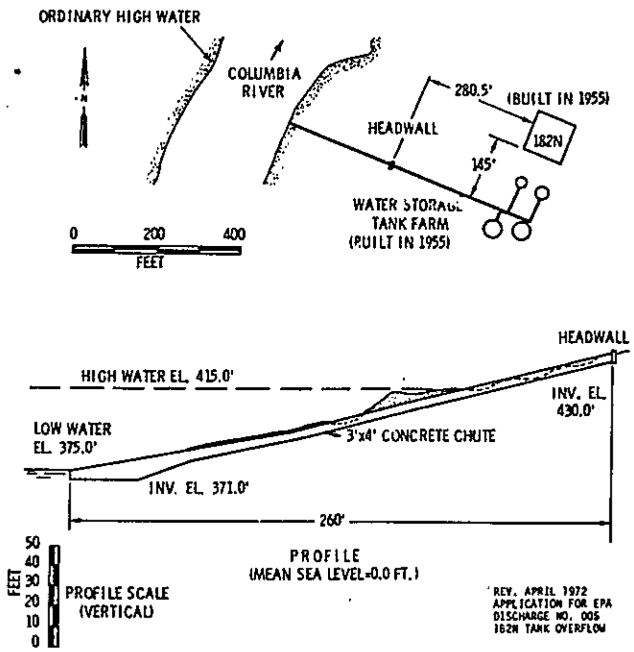

FIGURE II.1-D-6 WATER STORAGE TANK FARM OVERFLOW, 100-N AREA

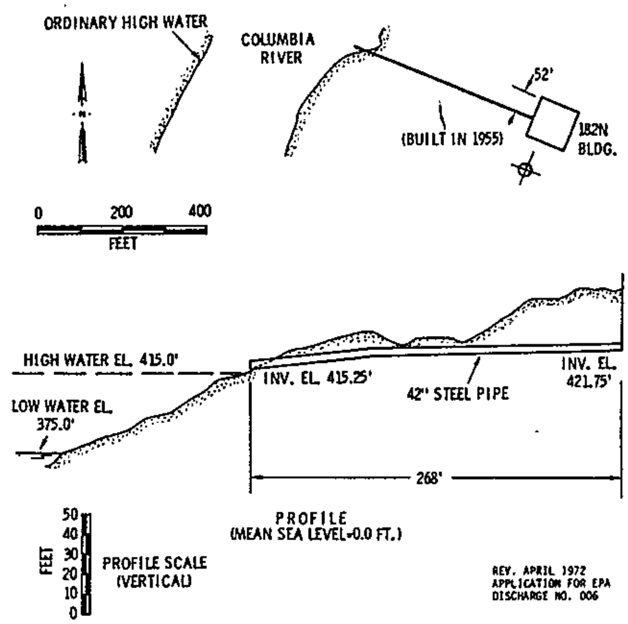

FIGURE II.1-D-7 OVERFLOW AND FLOOR DRAIN DISCHARGE, 100-N AREA

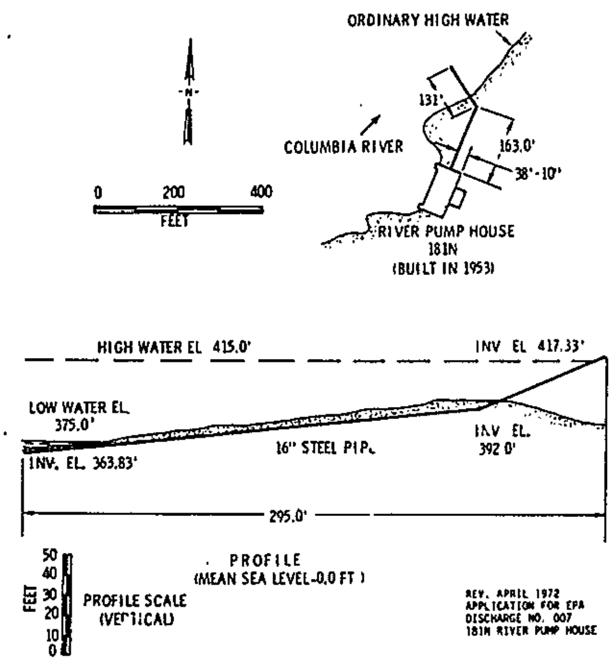

FIGURE II.1-D-8 INLET SCREEN WASH WATER, 100-N AREA

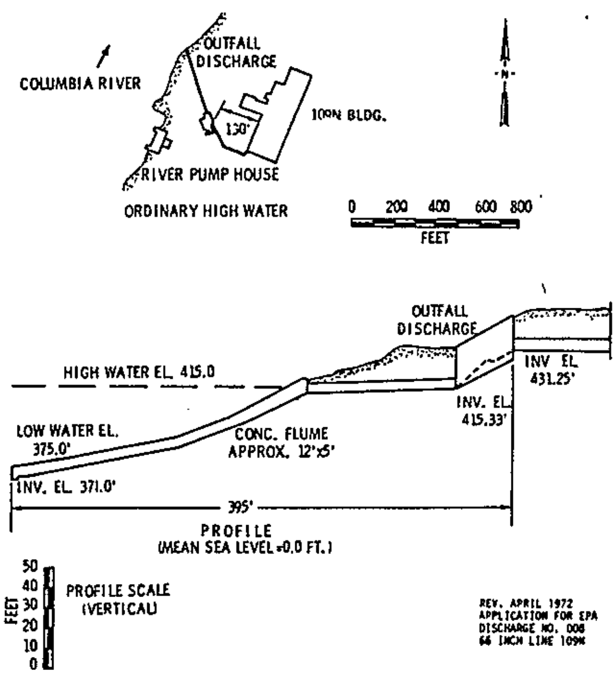

FIGURE II.1-D-9 TURBINE CONDENSER COOLING WATER, 100-N AREA

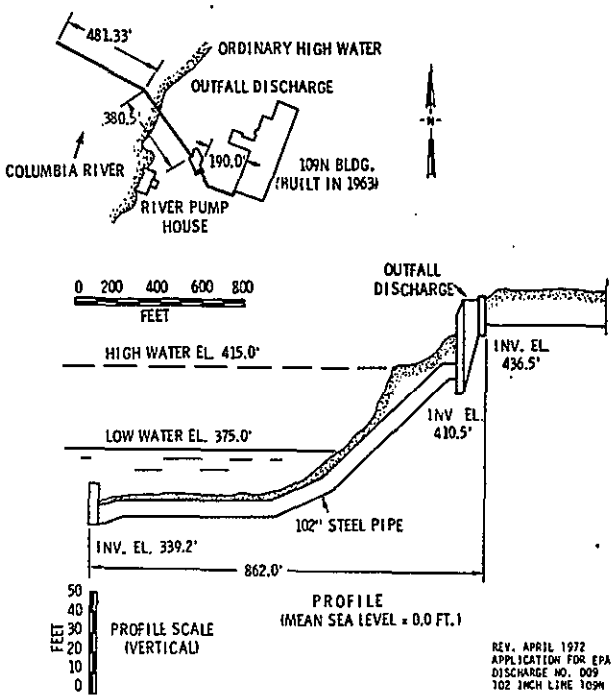

FIGURE II.1-D-10 DUMP CONDENSER COOLING WATER, 100-N AREA

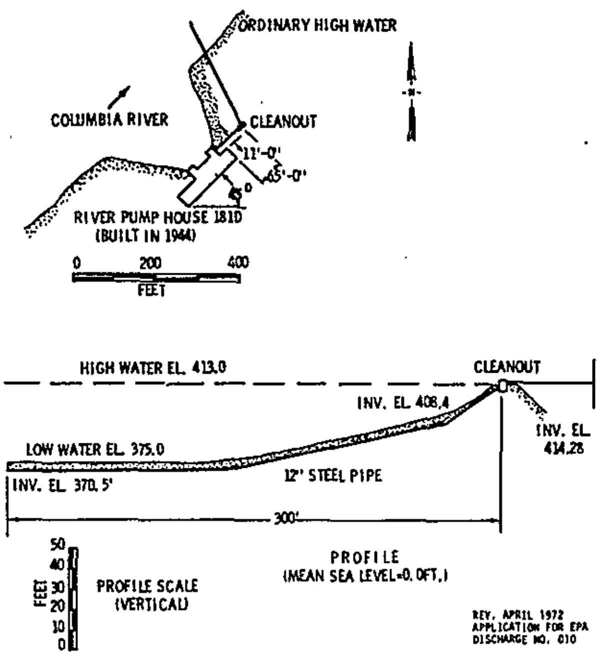

FIGURE II.1-D-11 INLET SCREEN WASH WATER, 100-D AREA

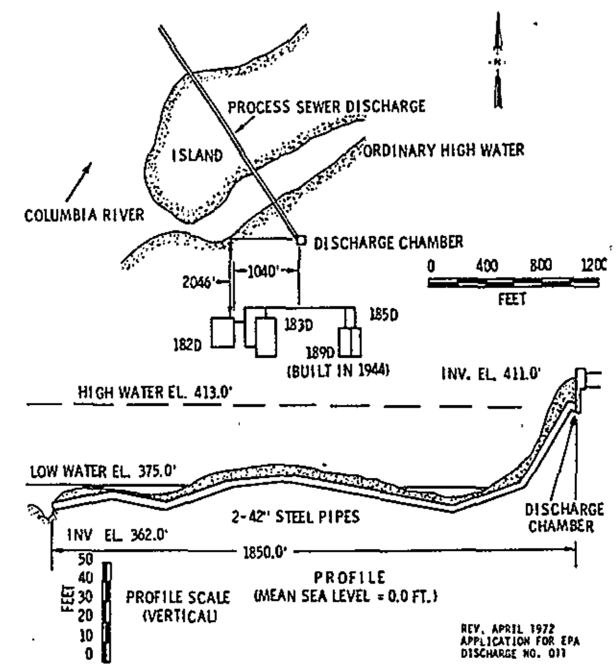

FIGURE II.1-D-12 RESEARCH FACILITY AND BACKWASH DRAIN, 100-D AREA

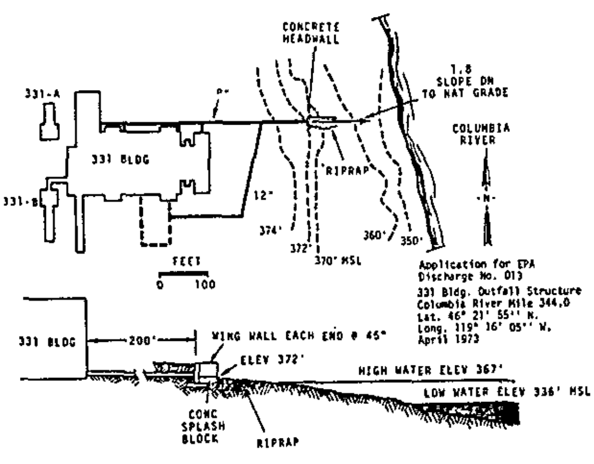

FIGURE II.1-D-13 331 BUILDING OUTFALL STRUCTURE

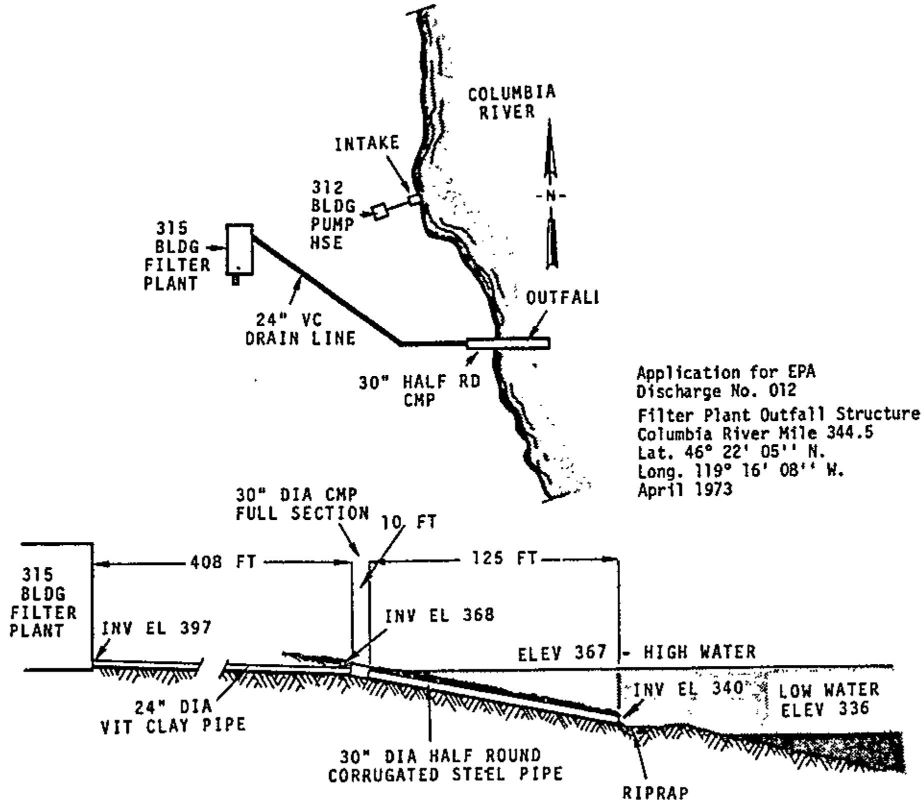

FIGURE II.1-D-14 FILTER PLANT OUTFALL STRUCTURE

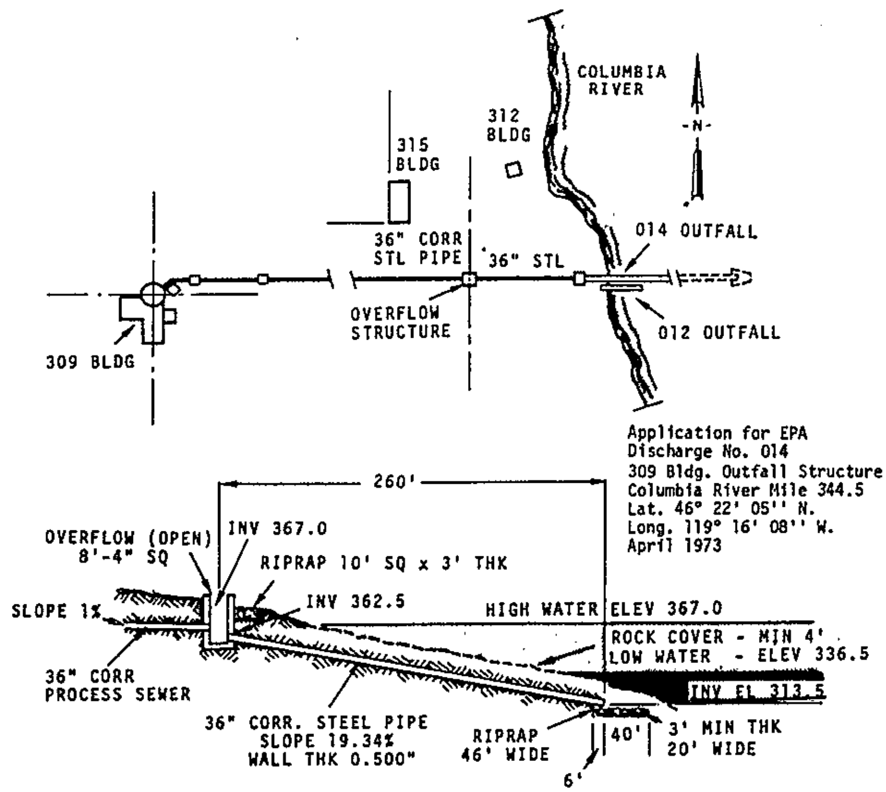

FIGURE II.1-D-15 309 BUILDING OUTFALL STRUCTURE

APPENDIX II.1-E

300 AREA FACILITIES

APPENDIX II.1-E

300 AREA FACILITIES

APPENDIX II.1-E, Part 1

300 Area Maps

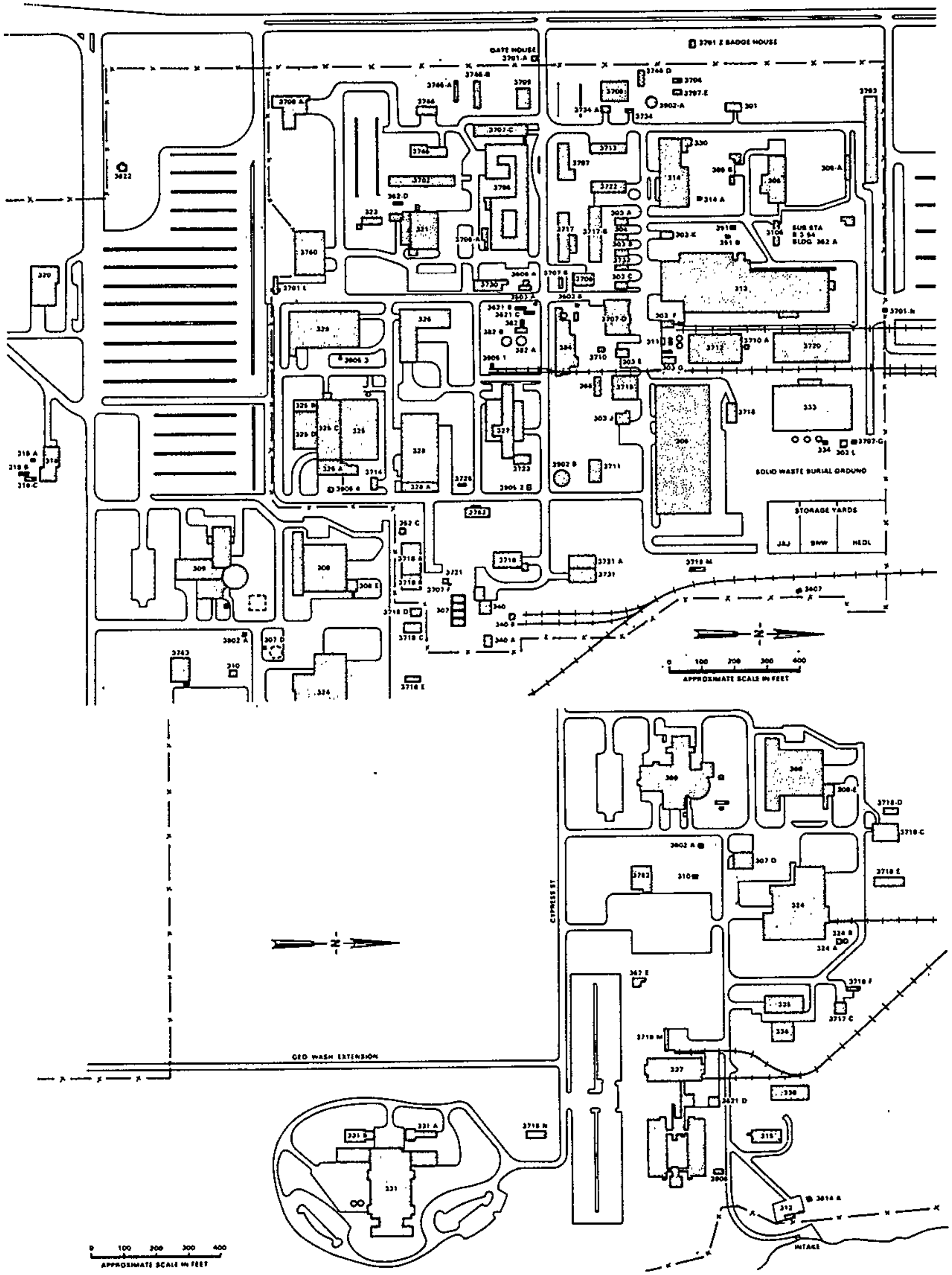

FIGURE II.1-E-1 300 AREA MAPS

BUILDINGS AND DESCRIPTIONS

BUILDING NUMBER	DESCRIPTION
301	EQUIPMENT STORAGE
303-A	PRODUCT STORAGE BUILDING
303-B	PRODUCT STORAGE BUILDING
303-C	FISSILE MATERIAL STORAGE BUILDING
303-E	ESSENTIAL MATERIAL STORAGE BUILDING
303-F	CHEMICAL STORAGE & DISPERSAL BUILDING
303-G	ESSENTIAL MATERIAL STORAGE BUILDING
303-J	MATERIAL STORAGE BUILDING
303-K	DECONTAMINATION AND BATTERY CHARGE BUILDING
303-L	OXIDE BURNING BUILDING
304	FUELS ENGINEERING LABORATORY
305	TEST REACTOR
305-A	OFFICE AND SHOP
305-B	EXPERIMENTAL TEST REACTOR BUILDING
306	METAL FABRICATION DEVELOPMENT
307	RETENTION BASIN
307-D	EFFLUENT HOLDUP TANK
308	PLUTONIUM LABORATORY
308-E	EMERGENCY STORAGE ANNEX
309	PRTR OFFICES AND SHOPS
310	PRTR CONDENSER BUILDING
311	ACID, CAUSTIC AND METHANOL TANK FARM
312	RIVER PUMP HOUSE
313	FUELS MANUFACTURING BUILDING
314	ENGINEERING DEVELOPMENT LABORATORY
314-A	GAS BONDING AUTOCLAVE PIT
315	WATER FILTER PLANT
318	HIGH TEMPERATURE LATTICE TEST REACTOR
318-A	DETECTOR BUILDING
318-B	HTLTR STACK
318-C	HTLTR FILTER
320	LOW LEVEL RADIOCHEMISTRY BUILDING
321	ENGINEERING DEVELOPMENT LABORATORY
323	METALS CREEP LABORATORY
324	CHEMICAL ENGINEERING LABORATORY
324-A	STACK GAS SAMPLING BUILDING
324 B	EXHAUST STACK
325	RADIOCHEMISTRY BUILDING
325-A	CESIUM RECOVERY FACILITY
325 B	SHIELDED LABORATORY ANNEX
325-C	FLORINE GAS STORAGE
325-D	MAINTENANCE SHOP
326	PHYSICS AND METALLURGY BUILDING
327	RADIOMETALLURGY BUILDING
328	ENGINEERING SERVICES AND SAFETY
328-A	TECHNICAL SHOPS ANNEX
329	BIOPHYSICS LABORATORY
330	STRESS RUPTURE TEST FACILITY
331	LIFE SCIENCE LABORATORY I
331 A	VIROLOGY LABORATORY
331-B	INHALATION FACILITY
333	N-FUELS MANUFACTURING BUILDING
334	CHEMICAL HANDLING BUILDING
335	SODIUM TESTING FACILITY
336	SODIUM TESTING FACILITY
337	HIGH TEMPERATURE SODIUM FACILITY
338	LMFBR MOCK-UP AND MAINTENANCE
340	RETENTION AND NEUTRALIZATION BUILDING
340-A	MAINTENANCE STORAGE
340 B	RAILROAD LOAD-OUT STATION
351	SUBSTATION
351-B	METER TESTING & SWITCHGEAR FACILITY
352	SUBSTATION - 2 4KV
352-A	SUBSTATION - 115KV
352-C	SUBSTATION - 2 4KV
352-D	2400 VOLT SWITCHGEAR BUILDING
352-E	SWITCH STATION EAST SIDE
366	FUEL OIL BUNKER
382	PUMP HOUSE
382-A	WATER RESERVOIR 200 000 GAL
382-B	WATER RESERVOIR 225 000 GAL
384	POWERHOUSE
3106	HELIUM STORAGE TANKS
3503-A	ELECTRICAL CABLE PIT NO 2
3503-B	ELECTRICAL CABLE PIT NO 3
3506-A	TELEPHONE EXCHANGE FACILITY

BUILDING NUMBER	DESCRIPTION
3607	SEPTIC TANK
3614-A	COLUMBIA RIVER MONITORING STATION
3621-B	EMERGENCY GENERATOR
3621-C	EMERGENCY GENERATOR CONTROL ROOM
3621-D	EMERGENCY POWER GENERATING STATION NO 3
3622	LABORATORY VIEWPOINT SHELTER
3701-A	GATE HOUSE - WEST
3701-L	BADGE HOUSE - SOUTH
3701-N	BADGE HOUSE - NORTH
3701-Z	BADGE HOUSE - CONSTRUCTION
3702	OFFICE BUILDING
3703	OFFICE BUILDING
3704	STORAGE
3705	PHOTOGRAPHY BUILDING
3706	OFFICES AND SERVICES
3706-A	VENTILATION EQUIPMENT BUILDING FOR 3706
3707-A	ENGINEERING
3707-B	UTILITY OPERATIONS BUILDING
3707-C	NONDESTRUCTIVE TESTING
3707-D	STORAGE
3707-E	STORAGE
3707-F	PERSONNEL SURVEY BUILDING
3707-G	URANIUM OXIDE CHANGE HOUSE
3708	FISSILE MATERIAL STORAGE
3709	PAINT SHOP
3709-A	FIRE STATION
3710	OIL AND GREASE STORAGE
3710-A	OIL AND GAS STORAGE
3711	STORAGE (CONSTRUCTION)
3712	FUEL MATERIAL STORAGE
3713	CARPENTER AND PAINT SHOP
3714	ORGANIC CHEMISTRY LABORATORY
3715	FUEL MATERIAL STORAGE
3716	METALLURGICAL DEVELOPMENT FACILITY
3717	SHEETMETAL SHOP AND OFFICE BUILDING
3717-B	STANDARDS LABORATORY
3717-C	SODIUM MAINTENANCE FACILITY
3718	PLANT OPERATIONS SERVICES BUILDING
3718-A	LABORATORY EQUIPMENT POOL
3718-B	LABORATORY EQUIPMENT POOL
3718-C	LABORATORY EQUIPMENT POOL
3718-D	LABORATORY STORAGE BUILDING (308)
3718-E	STORAGE BUILDING (324)
3718-F	SODIUM MAINTENANCE BUILDING
3718-M	SODIUM TANK STORAGE FACILITY
3718-N	CRAFT SUPPORT SHOP
3720	CENTRAL SERVICE & LABORATORY
3721	CLASSIFIED SCRAP INCINERATOR
3722	CONSTRUCTION SHOP
3723	SOLVENT & ACID STORAGE FOR 327
3726	PROPANE GAS STORAGE TANK
3730	GAMMA IRRADIATION FACILITY
3731	FISSILE MATERIAL STORAGE FACILITY
3731-A	GRAPHITE MACHINE SHOP
3732	STORAGE BUILDING
3734	MAINTENANCE STORAGE
3734-A	PAINT AND SOLVENT STORAGE
3745	RADIOLOGICAL CALIBRATIONS & STANDARDS BUILDING
3745-A	ELECTRON ACCELERATOR
3745-B	POSITIVE ION ACCELERATOR
3746	OFFICE BUILDING
3746-D	TECHNICAL SERVICES BUILDING
3760	TECHNICAL INFORMATION BUILDING
3762	OFFICE BUILDING
3763	OFFICE BUILDING
3802-A	PRV STATION
3902-A	ELEVATED TANK (WEST)
3902-B	ELEVATED TANK (EAST)
3905-1	WATER WELL
3905-2	WATER WELL
3905-3	WATER WELL
3905-4	WATER WELL
3906	SANITARY & PROCESS LIFT STATION

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APPENDIX II.1-E, Part 2

Waste Management Facilities Storage and Disposal Sites

TABLE II.1-E-1

TABLE OF 300 AREA STORAGE AND DISPOSAL SITES

Site	Size Acres	Description	Terminated Service In Year	Depth to Water Table (ft)	Monitored by Well Number
1	1.1	200 ft long trenches 15 ft wide by 8 ft deep on N-S axis and some 20 ft wide by 15 ft deep on E-W axis. Covered with 4 ft layer of clean dirt, and marked in 1961. Markers 3-61-51 through 3-61-90. Contains all 300 Area solid radioactive waste generated from 1945-1956, including uranium, plutonium, and fission products.	1956	41	399-1-2
2	1.7+	Pits 150 ft long by 51 ft wide by 15 ft deep. Covered with clean soil and marked in 1961. Markers 3-61-1 through 3-61-50. Contains uranium contaminated equipment and material.	1961	41	399-1-2
3	1.3+	An expansion to the west of No. 2 with similar contents and deactivation procedures.	1961	41	399-1-2
4	2.9+	Elongated pits containing uranium contaminated miscellaneous materials from 300 Area manufacturing facilities. Filled and covered with clean dirt. Marked in 1961 with markers 3-61-137 through 3-61-189.	1961	33	--
5	1.2+	Elongated pits to 15 ft deep containing uranium contaminated trash. Covered, filled with 4 ft of clean dirt. Marked in 1962, 3-62-1 through 3-62-38.	1962	38	
6	--	No longer exists. Wastes moved to other sites. Contained solid uranium waste from 6 mo in 1944. Filled with clean dirt.	1944	--	
7	~16.7	Two drive-in trenches and a V-shaped pit, containing materials primarily from 300 Area fuel manufacturing process contaminated slightly with uranium or thorium. Backfilled and covered with clean dirt.	1971	52	399-8-2
8	~1.4	Long trenches filled with low level uranium bearing waste from fuel manufacturing areas filled and covered with clean dirt and a parking lot (North). Marked in 1961, 3-61-91 through 136.	Prior	52	--
300 West	0.1	A long trench filled with drums of uranium contaminated organic solvent from the 321 Building in 1955 and 1956. Terminated and marked in 1963, 3-63-1 through 18.	1956	55	--
Contaminated Equipment Storage Area		All equipment removed. Ground slightly contaminated.			

TABLE II.1-E-2

TABLE OF STORAGE AND DISPOSAL SITES ANCILLARY TO THE 300 AREA

Site or Building No.	Size Acres	Description	Service	Depth To Water Table (ft)
300 North	6.1	Located about 4 miles northwest of 300 Area. Terminated. Broad spectrum of low-to high-level solid radioactive waste, primarily fission products and plutonium. Cartoned low-level waste was buried in trenches; medium to high-level waste in caissons or buried pipe facilities.	1953-63	65
300 North	<1	A stainless steel tank with an open bottom, about 150 ft southeast of the 300 North burial ground, into which was dumped uranium contaminated liquid waste from the 321 Building.	1948-56	65
300 Wye	8.6	Located about 7-1/3 miles north of the 300 Area. Retired--filled and marked. Broad spectrum of low-to high-level solid radioactive waste, primarily fission products and plutonium. Cartoned low-level waste was buried in trenches; medium to high-level waste in caissons or buried pipe facilities.	1962-67	45

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APPENDIX II.1-E, Part 3

Estimated Radioactive Liquid Waste Inventory

TABLE II.1-E-3

ESTIMATED RADIOACTIVE LIQUID WASTE INVENTORY - 300 AREA

340 STORAGE
75,000 GAL CAPACITY

Routine Analyses - Average Concentration (Ci/m^3)	Filtrate	Solids[a]
Total Beta[b]	7.2	43
Total Alpha[c]	0.011	0.033
^{60}Co	<0.006[d]	<0.046[d]
^{90}Sr	0.304	0.36
$^{106}Ru\text{-}Rh$	0.042[d]	0.40
^{137}Cs	0.321	0.038

Nuclides Detected in One or More Samples Concentration (Ci/m^3)	Filtrate[e]	Solids[a][e]
^{125}Sb	0.006(1)	0.013(3)
^{134}Cs	0.017(10)	0.003(2)
^{152}Eu		0.0003(1)
^{154}Eu	0.053(2)	0.003(4)
^{155}Eu	0.095(3)	0.042(5)
^{241}Am		0.0003(2)

The concentration of all nonradioactive chemical compounds is shown below:

Nonradioactive Analyses	Average
pH	11.5
Nonvolatile Residue	2600 g/m^3
Uranium Filtrate	31 g/m^3
Solids[a]	1.2 g/m^3

(a) Solids concentrations in units per cubic meter of liquid.
(b) Total beta calculated as a hypothetical, nonvolatile nuclide emitting a beta particle of energy 0.3 MeV.
(c) Total alpha is calculated as ^{239}Pu.
(d) "Less Than" is used when the results were below detection levels.
(e) The number in parenthesis indicates the number of values reported and averaged. Blanks indicate no value reported.

APPENDIX II.1-E, Part 4

Radioactive Material Releases, 1972

TABLE II.1-E-4

SUMMARY OF RADIOACTIVE GASEOUS WASTE DISCHARGED FROM 300 AREA FACILITIES DURING 1972

METAL FABRICATION DEVELOPMENT - 306-W

Roof No. 1 - Thorium Storage Room

Volume 1×10^{13} (cc)	Alpha	Beta
Ave. Concentration	$<1.1 \times 10^{-14}$ μCi/cc	$<1.2 \times 10^{-13}$ μCi/cc
Ave. Release Rate	<0.001 μCi/wk	<0.024 μCi/wk
Max. Release	<0.011 μCi/wk	<0.051 μCi/wk
Total Release	<0.052 μCi	<1.2 μCi

METAL FABRICATION DEVELOPMENT - 306-W

Roof No. 2 - Bag Filter Exhaust

Volume 2×10^{14} (cc)	Alpha	Beta
Ave. Concentration	$<1.2 \times 10^{-14}$ μCi/cc	$<1.8 \times 10^{-13}$ μCi/cc
Ave. Release Rate	<0.046 μCi/wk	<0.73 μCi/wk
Max. Release	<0.17 μCi/wk	<2.3 μCi/wk
Total Release	<2.4 μCi	<39 μCi

METAL FABRICATION DEVELOPMENT - 306-W

Volume 1×10^{14} (cc)	Alpha	Beta
Ave. Concentration	$<3.2 \times 10^{-14}$ μCi/cc	$<2.6 \times 10^{-13}$ μCi/cc
Ave. Release Rate	<0.065 μCi/wk	<0.53 μCi/wk
Max. Release Rate	<0.42 μCi/wk	<1.8 μCi/wk
Total Release	<3.4 μCi	<27 μCi

306-W METAL FABRICATION DEVELOPMENT

URANIUM POWDER LABORATORIES NO. 158 AND NO. 159

Volume 3.1×10^{13} (cc)	Alpha	Beta
Ave. Concentration	$<5.0 \times 10^{-15}$ μCi/cc	$<3.6 \times 10^{-14}$ μCi/cc
Ave. Release Rate	<0.003 μCi/wk	<0.02 μCi/wk
Max. Release Rate	<0.02 μCi/wk	<0.08 μCi/wk
Total Release	<0.16 μCi	<1.1 μCi

BIOPHYSICS LABORATORY - 329

Volume 4×10^{14} (cc)	Alpha	Beta
Ave. Concentration	$<0.35 \times 10^{-14}$ μCi/cc	$<2.2 \times 10^{-14}$ μCi/cc
Ave. Release Rate	<0.29 μCi/wk	<0.19 μCi/wk
Max. Release Rate	<0.38 μCi/wk	<0.53 μCi/wk
Total Release	<1.5 μCi	<9.7 μCi

LIFE SCIENCE BUILDING - 331

	"D" Stack, Alpha[a]	"S" Stack, Alpha[a]
Volume	1.7×10^{8}	5.6×10^{8}
Ave. Concentration	$<3.1 \times 10^{-10}$ pCi/cc	$<1.9 \times 10^{-10}$ pCi/cc
Ave. Release Rate	<0.003 μCi/wk	<0.002 μCi/wk
Max. Release Rate	<0.011 μCi/wk	<0.024 μCi/wk
Total Release	<0.052 μCi	<0.11 μCi

(a) As plutonium.

TABLE II.1-E-4 (Continued)

FISSILE MATERIAL STORAGE - 3708

	Alpha
Volume 4 x 10^{13} (cc)	
Ave. Concentration	<4.4 x 10^{-15} μCi/cc
Ave. Release Rate	<0.0048 μCi/wk
Max. Release Rate	<0.008 μCi/wk
Total Release	<0.17 μCi
Facility put into service	May 1, 1972.

308 FUELS LABORATORY

	Alpha
Volume 3.3 x 10^{14} (cc)	
Ave. Concentration	<4.5 x 10^{-15} μCi/cc
Ave. Release Rate	<0.03 μCi/wk
Max. Release Rate	<0.03 μCi/wk
Total Release	<1.5 μCi

324 CHEMISTRY AND MATERIALS ENGINEERING LABORATORY

	Alpha	Beta	Iodine-131
Volume 1 x 10^{15} (cc)			
Ave. Concentration	<3.1 x 10^{-14} μCi/cc	<7.9 x 10^{-14} μCi/cc	<7.8 x 10^{-13} μCi/cc
Ave. Release Rate	<0.38 μCi/wk	<2.5 μCi/wk	<26 μCi/wk
Max. Release Rate	<0.4 μCi/wk	<3.2 μCi/wk	<48 μCi/wk
Total Release	<20 μCi	<140 μCi	<1400 μCi/wk

325 RADIOCHEMISTRY LABORATORY

	Alpha	Beta	Iodine-131
Volume 2 x 10^{15} (cc)			
Ave. Concentration	7.8 x 10^{-15} μCi/cc	1.2 x 10^{-12} μCi/cc	<1.3 x 10^{-12} μCi/cc
Ave. Release Rate	<0.22 μCi/wk	52 μCi/wk	28 μCi/wk
Max. Release Rate	0.93 μCi/wk	910 μCi/wk	380 μCi/wk
Total Release[a]	<12 μCi	2800 μCi	<1500 μCi

(a) 1 Ci Radon release on September 25, 1972.

325-B RADIOCHEMISTRY LABORATORY ANNEX

	Alpha	Beta	Iodine-131
Volume 1 x 10^{14} (cc)			
Ave. Concentration	<5.4 x 10^{-15} μCi/cc	1.9 x 10^{-13} μCi/cc	1.1 x 10^{-11} μCi/cc
Ave. Release Rate	<0.008 μCi/wk	<0.3 μCi/wk	19 μCi/wk
Max. Release Rate	0.02 μCi/wk	10 μCi/wk	310 μCi/wk
Total Release[a]	<0.44 μCi	<16 μCi	1000 μCi

(a) 1 Ci Radon release on July 26, 1972.

TABLE II.1-E-4 (Continued)

326 PHYSICS AND METALLURGY

	Alpha	Beta
Volume 1 x 10^{15} (cc)		
Ave. Concentration	<8.3 x 10^{-15} μCi/cc	5.6 x 10^{-14} μCi/cc
Ave. Release Rate	<0.34 μCi/wk	1.0 μCi/wk
Max. Release Rate	0.67 μCi/wk	2.9 μCi/wk
Total Release	<18 μCi	55 μCi

327 RADIOMETALLURGY LABORATORY

	Alpha[(a)]	Beta[(b)]	Iodine-131
Volume 1 x 10^{15} (cc)			
Ave. Concentration	5.6 x 10^{-15} μCi/cc	<3.4 x 10^{-14} μCi/cc	7.6 x 10^{-12} μCi/cc
Ave. Release Rate	<0.1 μCi/wk	<0.66 μCi/wk	160 μCi/wk
Max. Release Rate	0.34 μCi/wk	0.84 μCi/wk	3000 μCi/wk
Total Release	<5.5 μCi	<34 μCi	8100 μCi

(a) Alpha activity was presumed to have the same plutonium composition as the fuel being examined: 88.3% ^{239}Pu, 10.3% ^{240}Pu, 1.3% ^{241}Pu and 0.1% ^{242}Pu. In this mixture 95% of the alpha particles emitted come from ^{241}Pu.
(b) Beta emitters were not identified. There were larger amounts of fission products than activation products in samples being examined.

340 TANK VENT

	Alpha	Beta	Iodine-131
Volume 5 x 10^{12} (cc)			
Ave. Concentration	<4.3 x 10^{-13} μCi/cc	6.7 x 10^{-11} μCi/cc	1.4 x 10^{-10} μCi/cc
Ave. Release Rate	<0.012 μCi/wk	5.0 μCi/wk	16 μCi/wk
Max. Release Rate	0.41 μCi/wk	220 μCi/wk	370 μCi/wk
Total Release	<0.60 μCi	290 μCi	780 μCi

TABLE II.1-E-5

ESTIMATED RADIOACTIVE LIQUID RELEASES TO THE 300 AREA PROCESS PONDS-1972[(a)]

	Uranium[(b)]		Total Alpha	Total Beta
Average Flow Rate	2.9 x 10^{6} gal/day			
Total Discharge	530 kg	0.4 Ci	0.38 Ci	0.48 Ci
Average Concentration	130 μg/liter		96 x 10^{-9} μCi/ml	120 x 10^{-9} μCi/ml

(a) The 300 Area South Pond was used for 5 days in 1972.
(b) Analysis of accumulated solids indicated 0.977% ^{235}U. On this basis the specific activity was determined to be 8.4 x 10^{-7} Ci/g.

APPENDIX II.1-E, Part 5

Unplanned Releases

TABLE II.1-E-6

300 AREA UNPLANNED RELEASES

Date	Building	Description	Nuclide and Amount
1-7-70	307,340	A leak was discovered in the transfer line from retention basins to crib waste system. Crib waste backed up and the bottom half of a short carbon steel transition piece was eroded away and contaminated waste leaked to the soil about 5 feet below grade.	840 Ci Shortlived F.P. 10 Ci ^{90}Sr 10 Ci ^{137}Cs
6-7-69	325-B	Stack release from 325-B. (^{131}I) Sample showed additional emission ~3 mCi. Alpha and total beta release low and normal.	0.6 Ci ^{131}I
6-13-67	325	Nonstandard release of ^{147}Pm from 325 Bldg. 0.71 Ci to 300 Area pond. 0.1 Ci to atm via 325 stack.	0.85 Ci ^{147}Pm
5-09-67	327	Release of iodine resulted from examination of irradiated reactor fuel.	0.11 Ci ^{131}I
5-09-66	325	Daily check of stack filters detected $^{144-141}$Ce had been released.	0.6 Ci $^{144-141}$Ce
3-23-67 thru 4-18-67	300 Area Stacks 325 Stacks	^{131}I releases in excessive amounts from 300 Area stacks.	0.2 Ci ^{131}I
5-03-67	327	Release of iodine during the sectioning off of PRTR fuels.	0.1 Ci ^{131}I
9-29-65	309 Bldg.	Failure of reactor coolant tube caused high radiation limits inside reactor and containment vessel.	
No significant releases 1958-1964[(a)]			
8-16-55	300 North Burial Grounds	Fire caused particulates to be spread out to 1500 ft in a northeast direction. Particle frequencies ranged from 0.5 to 4 per 100 ft^2. Instrument readings of 35,000 to 80,000 counts/min. Isolated 4.5 rad/hr.	Mixed
2-17-54	Burial Ground	Fire occurred in 300 Area solid waste burial ground. Small area east of and up to 20 ft from BG fence contained widely scattered contamination from 2000 counts/min to 100 mrad/hr	Mixed

(a) G. E. Backman, Summary of Environmental Contamination Incidences at Hanford, 1958-1964, HW 84619, April 1965.

APPENDIX II.1-F

PROCESS CHEMICAL INVENTORY AND CONSUMPTION

TABLE II.1-F-1

PROCESS CHEMICAL INVENTORY - 200 AREAS

Chemical Compound	How Stored	Where Stored	How Used	How Disposed	Typical Inventory
Aluminum Nitrate - Nonahydrate	Bulk Tank	202-A Bldg. 234-5 Bldg.	Process Chemical Process Chemical	Underground Storage Tank Underground Storage Tank	30,000 lb
Ammonium Fluoride Ammonium Nitrate	Bulk Tank	202-A Bldg.	Process Chemical	Underground Storage Tank	100,000 lb
Ammonia (Anhydrous)	Bulk Tank	271-B Bldg.	Process Chemical	Underground Storage Tank	45,000 lb
Carbon Tetrachloride	Drum	234-5 Bldg.	Process Chemical	Underground Storage Tank	20,000 lb
Carbon Dioxide	Bulk Tank	271-B Bldg.	Process Chemical	Underground Storage Tank	30,000 lb
Citric Acid	100 lb. Bag	275-EA Warehouse 271-B Bldg. 271-T Bldg.	Process Chemical Process Chemical Cleaning Agent	To User Facility Underground Storage Tank Underground Storage Tank	100,000 lb
Cadmium Nitrate	55 gal Drum	275-EA Warehouse	Neutron Poison Neutron Poison	Z-9 Crib Underground Storage Tank	15,000 lb
Dibutyl Butyl Phosphonate	55 gal Drum	275-EA Warehouse 234-5 Bldg.	Process Chemical Process Chemical	To User Facility Underground Storage Tank	11,000 lb
Di2 Ethyl Hexyl Phosphoric Acid	55 gal Drum	275-EA Warehouse 271-B Bldg.	Process Chemical Process Chemical	To User Facility Underground Storage Tank	10,000 lb
Ferric Nitrate	Fiber Drum	275-EA Warehouse 202-A Bldg.	Process Chemical Process Chemical	To User Facility Underground Storage Tank	6,000 lb
Ferrous Sulfamate	Fiber Drum	275-EA Warehouse 202-A Bldg.	Process Chemical Process Chemical	To User Facility Underground Storage Tank	5,000 lb
Magniflox 581C	55 gal Drum	275-EA Warehouse 244-AR Bldg.	Process Chemical Process Chemical	To User Facility Underground Storage Tank	10,000 lb
Hydrogen Fluoride	Cylinder	234-5 Bldg.	Process Chemical	Underground Storage Tank	10,000 lb
Hydroxyacetic Acid	Bulk Tank	271-B Bldg.	Process Chemical	Underground Storage Tank	200,000 lb
Hydrogen Peroxide	Aluminum Drum	275-EA Warehouse 234-5 Bldg.	Process Chemical Process Chemical	To User Facility Underground Storage Tank	1,500 lb
Calcium	Drum	234-5 Bldg.	Process Chemical	Underground Storage Tank	1,500 lb
Magnesium Oxide	Drum	234-5 Bldg.	Process Chemical	Underground Storage Tank	3,000 lb
Liquid Nitrogen	Bulk Tank	234-5 Bldg.	Process Chemical	Atmosphere	150,000 ft^3
Hydrochloric Acid	Bottle	275-EA Warehouse	Process Chemical	To User Facility Underground Storage Tank	1,000 lb
Hydroxylamine Sulfate	Drum	275-EA Warehouse 234-5 Bldg.	Process Chemical Process Chemical	To User Facility Underground Storage Tank	20,000 lb
Lead Nitrate(b)	Wooden Keg (polylined)	275-EA Warehouse	Process Chemical	To User Facility	5,000 lb
Mercuric Nitrate	Ice Cream Carton (polylined)	275-EA Warehouse	Process Chemical	To User Facility Underground Storage Tank	350 lb
Tetra Sodium Ethylene Diamine Tetra Acetate (EDTA)	Bulk Tank	271-B Bldg.	Process Chemical	Underground Storage Tank	250,000 lb
Nitrilotriacetic Acid (b)	55 gal Drum	275-EA Warehouse	Process Chemical	To User Facility	3,000 lb
Trisodium Hydroxyethyl Ethylene Diamine Triacetate (HEDTA)	Bulk Tank	271-B Bldg.	Process Chemical	Underground Storage Tank	400,000 lb
Normal Paraffin Hydrocarbon	Bulk Tank	202-A Bldg. 271-B Bldg.	Process Chemical Process Chemical	Underground Storage Tank Underground Storage Tank	200,000 lb
Nitric Acid	Bulk Tank Bulk Tank Bulk Tank Bulk Tank Bulk Tank Bulk Tank	202-A Bldg. 234-5 Bldg. 271-B Bldg. 244-AR Bldg. 271-T Bldg. 211-U Bldg.	Process Chemical Process Chemical Process Chemical Process Chemical Cleaning Agent Process Chemical	Underground Storage Tank Underground Storage Tank Underground Storage Tank Underground Storage Tank Underground Storage Tank Underground Storage Tank	200,000 lb
Oxalic Acid	Fiber Drum (polylined)	275-EA Warehouse 271-B Bldg. 234-5 Bldg.	Process Chemical Process Chemical Process Chemical	To User Facility Underground Storage Tank Underground Storage Tank	15,000 lb

TABLE II.1-F-1 (Continued)

Chemical Compound	How Stored	Where Stored	How Used	How Disposed	Typical Inventory
Pentasodium Diethylene Triamine Penta-acetate (b) (DTPA)	55 gal Drum	275-EA Warehouse	Process Chemical	To User Facility Underground Storage Tank	1,200 lb
Phosphotungstic Acid	Steel Drum	275-EA Warehouse	Process Chemical	To User Facility Underground Storage Tank	2,500 lb
Phosphoric Acid	Bulk Tank (polylined) Fiber Drum	241-BX Tank Farm 275-EA Warehouse	Process Chemical Process Chemical	To User Facility To User Facility Underground Storage Tank	15,000 lb
Potassium Hydroxide	Bulk Tank	202-A Bldg.	Process Chemical	Underground Storage Tank	35,000 lb
Potassium Permanganate	Steel Pail (polylined)	275-EA Warehouse 234-5 Bldg. 271-T Bldg. 284-E Bldg. 284-W Bldg.	Process Chemical Process Chemical Cleaning Agent Water Treatment Water Treatment	To User Facility Underground Storage Tank Underground Storage Tank Sanitary Water Sanitary Water	8,000 lb
Potassium Persulfate (b)	100 lb. Bag	275-EA Warehouse	Process Chemical	To User Facility Underground Storage Tank	4,000 lb
Silver Nitrate (b)	Ice Cream Carton (polylined)	275-EA Warehouse	Process Chemical	To User Facility Underground Storage Tank	1,000 lb
Sodium Bisulfate	Fiber Drum (polylined)	275-EA Warehouse 271-T Bldg.	Process Chemical Cleaning Agent	To User Facility Underground Storage Tank	125,000 lb
Soda Ash	100 lb Bag	275-EA Warehouse 202-A Bldg. 271-B Bldg. 271-T Bldg.	Process Chemical Process Chemical Process Chemical Cleaning Agent	To User Facility Underground Storage Tank Underground Storage Tank Underground Storage Tank	250,000 lb
Sodium Chloride	100 lb Bag	284-E Bldg. 284-W Bldg.	Water Treatment Water Treatment	Seepage Pond Seepage Pond	150,000 lb
Sodium Fluoride	100 lb Bag	275-EA Warehouse	Process Chemical	Underground Storage Tank	500 lb
Sodium Fluoride (Reagent Grade)	200 lb Fiber Drum	275-EA Warehouse	Process Chemical	To User Facility	1,000 lb
Sodium Gluconate	50 lb Bag	275-EA Warehouse 271-B Bldg.	Process Chemical Process Chemical	To User Facility Underground Storage Tank	100,000 lb
Sodium Hydroxide.	Bulk Tank	202-A Bldg. 271-B Bldg. 234-5 Bldg. 244-AR Bldg. 271-T Bldg.	Process Chemical Process Chemical Process Chemical Process Chemical Process Chemical	Underground Storage Tank Underground Storage Tank Underground Storage Tank Underground Storage Tank Underground Storage Tank	300,000 lb
Sodium Nitrate	100 lb Bag	275-EA Warehouse 234-5 Bldg.	Process Chemical	To User Facility Underground Storage Tank	50,000 lb
Sodium Nitrite	100 lb Bag Fiber Drum	275-EA Warehouse	Process Chemical	To User Facility Underground Storage Tank	50,000 lb
Sodium Sulfate	100 lb Bag	275-EA Warehouse 271-B Bldg.	Process Chemical Process Chemical	To User Facility Underground Storage Tank	75,000 lb
Sugar	100 lb Bag	275-EA Warehouse	Process Chemical	To User Facility Underground Storage Tank	5,000 lb
Sulfanic Acid	50 lb Bag	275-EA Warehouse	Process Chemical	To User Facility Underground Storage Tank	4,300 lb
Sulfuric Acid	Bulk Tank	20?-A Bldg. 211-U Bldg.	Water Treatment Process Chemical	Seepage Pond In Product	100,000 lb
Hydrazine	Steel Drum	275-EA Warehouse 234-5 Bldg.	Process Chemical	To User Facility Underground Storage Tank	10,000 lb
Tartaric Acid	Burlap Sack	275-EA Warehouse	Process Chemical	To User Facility Underground Storage Tank	20,000 lb
Tributyl Phosphate	Bulk Tank 55 gal Drum	202-A Bldg. 234-5 Bldg. 271-B Bldg. 275-EA Warehouse	Process Chemical Process Chemical Process Chemical Process Chemical	Underground Storage Tank Underground Storage Tank Underground Storage Tank To User Facility	25,000 lb
Turco 4306B	Fiber Drum (polylined)	275-EA Warehouse	Cleaning Agent	To User Facility Underground Storage Tank	12,000 lb
Turco 4518	55 gal Drum (polylined)	275-EA Warehouse 271-T Bldg.	Cleaning Agent Cleaning Agent	To User Facility Underground Storage Tank	6,000 lb

TABLE II.1-F-1 (Continued)

Chemical Compound	How Stored	Where Stored	How Used	How Disposed	Typical Inventory
Turco 4512-A	55 gal Drum	275-EA Warehouse 271-T Bldg.	Cleaning Agent Cleaning Agent	To User Facility Underground Storage Tank	200 gal
Aluminum Sulfate	100 lb Sack	275-EA Warehouse 284-E Bldg. 284-W Bldg.	Water Treatment Water Treatment Water Treatment	To User Facility Seepage Pond Seepage Pond	80,000 lb
Chlorine	Cylinder	284-E Bldg. 284-W Bldg.	Water Treatment Water Treatment	Sanitary Water Sanitary Water	20,000 lb
Disodium Phosphate	100 lb Sack	275-EA Warehouse 284-E Bldg. 284-W Bldg.	Water Treatment Water Treatment Water Treatment	To User Facility Seepage Pond Seepage Pond	2,500 lb
Octafilm	Fiber Drum	275-EA Warehouse 284-E Bldg. 284-W Bldg.	Water Treatment Water Treatment Water Treatment	To User Facility French Drains and Cribs	15,000 lb
Sodium Sulfite	100 lb Sack	275-EA Warehouse 284-E Bldg. 284-W Bldg.	Water Treatment Water Treatment Water Treatment	To User Facility Seepage Pond Seepage Pond	5,000 lb
Corregen	55 gal Drum	275-EA Warehouse 284-E Bldg.	Water Treatment	To User Facility French Drains and Cribs	5,000 lb
Agel	Fiber Drum	275-EA Warehouse 284-E Bldg. 284-W Bldg.	Water Treatment Water Treatment Water Treatment	To User Facility French Drains and Cribs	15,000 lb

TABLE II.1-F-2

B PLANT CHEMICAL CONSUMPTION

Chemical	Consumption (lb/yr) PAS + PSS(a)	CAW(b)
Ammonia	600,000	- -
Carbon Dioxide	700,000	- -
Citric Acid		300,000
Di(2-Ethylhexyl) Phosphoric Acid (D2EHPA)	25,000	10,000
Hydroxyacetic Acid	300,000	250,000
Tetra Sodium Ethylene Diamine Tetra Acetate (EDTA)	1,500,000	- -
Tri Sodium Hydroxyethyl Ethylene Diamine Triacetate (HEDTA)	2,000,000	15,000
Normal Paraffin Hydrocarbon (NPH)	85,000	30,000
Nitric Acid	1,500,000	1,000,000
Oxalic Acid	4,000	3,000
Phosphotungstic Acid (PTA)	- -	22,000
Sodium Carbonate (Soda Ash)	100,000	650,000
Sodium Glucomate	100,000	70,000
Sodium Hydroxide (Caustic)	1,800,000	1,600,000
Sodium Sulfate	50,000	40,000
Sulfuric Acid	3,000	2,000
Tributyl Phosphate (TBP)	15,000	6,000

(a) SX Operating 70% of time - 200,000 gal sludge per year
(b) SX Operating 50% of time - 250,000 gal CAW per year (from 1,000 T/YR N Reactor fuels)

TABLE II.1-F-3

ENCAPSULATION PLANT CHEMICAL CONSUMPTION

Hydrochloric Acid (12M solution)	945 liters/year
Sodium fluoride (Solid)	1,000 pounds/year
Sodium Hydroxide (Solid)	900 pounds/year
(Liquid)	700 liters/year
Nitric Acid 57%	82,000 liters/year
Boric Acid	2,000 pounds/year

TABLE II.1-F-4

TANK FARMS CHEMICAL CONSUMPTION

Chemical		Quantity/Yr
Nitric Acid 57%	Now	1,000,000 lb
	Future	3-10 million lb
Magnifloc 581C		15,000 lb
Sodium Hydroxide		120,000 lb
Turco 4518		1,300 lb
Fabrifilm		55 lb
Sodium Nitrate		100,000 lb
Phosphoric Acid		2-3 million lb/yr during 1976, 77, 78, 79
or		or
Kaolin Clay		10-15 million lb/yr during 1976, 77, 78, 79

TABLE II.1-F-5

PUREX PLANT CHEMICAL CONSUMPTION

Chemical	lb/yr[(a)]	N Fuels lb/ton
Aluminum Nitrate (ANN)	275,000	270
Ammonium Fluoride - Ammonium Nitrate (AFAN)	700,000	670
Ferric Nitrate	750	
Ferrous Sulfamate	20,000	20
Normal Paraffin Hydrocarbon (NPH)	16,000	16
Nitric Acid (HNO_3)	900,000	900
Oxalic Acid	20,000	
Potassium Hydroxide (KOH)	160,000	160
Potassium Permanganate	2,000	2.0
Sodium Carbonate (Soda Ash)	10,000	9.9
Sodium Hydroxide (Caustic)	650,000	650
Sodium Nitrite	15,000	13
Sugar	30,000	27
Sulfamic Acid	5,000	5.4
Sulfuric Acid	25,000	25
Hydrazine	4,000	3.3
Tartaric Acid	6,000	
Tributyl Phosphate (TBP)	100,000	
Hydroxylamine Nitrate	20,000	5 gal
Potassium Fluoride	25,000	
Cadmium Nitrate	5,000	

(a) Assumes 1,000 T/Yr of N Reactor fuels

TABLE II.1-F-6

CHEMICAL CONSUMPTION FOR Pu RECLAMATION AND Pu FINISHING (Z PLANT)

Chemical	Quantity/Yr
Aluminum Nitrate Nonahydrate[a]	450,000 lb
Carbon Tetrachloride[a]	11,000 gal
Ca metal[b]	1,500 lb
Magnesium Oxide[b]	2,000 lb
RS-6 Crucible[b]	700 ea
Dibutyl Butyl Phosphonate[a]	3,520 lb
Hydrogen Fluoride[b]	10,000 lb
Hydrogen Peroxide[b]	1,000 lb
Hydroxylamine Sulfate[a]	20,000 lb
Mercuric Nitrate[a]	100 lb
Nitric Acid 57%[a]	350,000 lb
Liquid Nitrogen[a]	5,500,000 ft^3
Oxalic Acid[b]	8,000 lb
Potassium Permanganate[b]	300 lb
Soda Ash[a]	200 lb
Caustic[a]	200,000 lb
Sodium Nitrate[a]	8,000 lb
Sodium Nitrite[a]	800 lb
Hydrazine - Scarox[a]	2,500 lb
Tributyl Phosphate[a]	8,000 lb

(a) Pu Reclamation
(b) Pu Finishing

TABLE II.1-F-7

POWER AND WATER CHEMICAL CONSUMPTION

Chemical	lb/yr
Aluminum Sulfate	90,000
Chlorine	9,000
Disodium Phosphate	6,000
Filming Amine (Octafilm)	24,000
Salt	500,000
Sodium Sulfite	14,000
AGEL	15,000
Potassium Permangate	2,500
Corregen	8,000

TABLE II.1-F-8

FUEL FABRICATION PROCESS CHEMICALS (300 AREA)

Chemical	Typical Inventory Gallons
Nitric Acid	10,000
Sulfuric Acid	6,000
Sodium Hydroxide	20,000
Trichlorethylene	10,000

TABLE II.1-F-9

SANITARY AND PROCESS WATER TREATMENT CHEMICALS (100 AND 300 AREAS)

Chemical	Typical Inventory Gallons
Aluminum Sulfate	16,000
Sulfuric Acid	30,000
Ammonium Hydroxide	8,000
Hydrazine	1,700
Morpholine	900
Sodium Dichromate	150
Chlorine (Liquid)	1 ton Cylinders

TABLE II.1-F-10

PROCESS CHEMICAL CONSUMPTION-1972

		100-B	100-D	100-K	100-N	300	Total
Aluminum Nitrate	Lbs					24,000	24,000
Aluminum Sulfate	Lbs	84,000	40,000	340,000	330,000	24,000	840,000
Ammonium Bifluoride	Lbs					24,000	24,000
Bauxite	Lbs			220,000			220,000
Calcium Carbonate (Lime)	Lbs					200,000	200,000
Chlorine	Lbs	23,000	10,000	75,000	28,000	6,000	140,000
Hydrazine	Lbs				18,000		18,000
Hydrofluoric Acid	Lbs					2,400	2,400
Methanol	Lbs					2,600	2,600
Morpholine	Lbs				4,100		4,100
Nitric Acid	Lbs					520,000	520,000
Oxalic Acid	Lbs					900	900
Polyacrylamide	Lbs	150	150	4,500	1,200	300	6,300
Salt (Rock)	Lbs			3,700			3,700
Sodium Dichromate	Lbs			30,000	9,000		39,000
Sodium Hydroxide	Lbs				540,000	250,000	790,000
Sodium Nitrate	Lbs					17,000	17,000
Sulfuric Acid	Lbs			1800,000	1200,000	44,000	3100,000
Trichlorethylene	Lbs					66,000	66,000
Copper	Lbs					14,000	14,000
Ammonium Hydroxide	Gals				33,000		33,000

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APPENDIX II.1-G

NONRADIOACTIVE ENVIRONMENTAL

STANDARDS APPLICABLE TO HANFORD WASTE MANAGEMENT OPERATIONS

APPENDIX II.1-G

NONRADIOACTIVE ENVIRONMENTAL

STANDARDS APPLICABLE TO HANFORD WASTE MANAGEMENT OPERATIONS

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(vii) Toxic, radioactive, or deleterious material concentrations shall be below those of public health significance, or which may cause acute or chronic toxic conditions to the aquatic biota, or which may adversely affect any water use.

(viii) Aesthetic values shall not be impaired by the presence of materials or their effects, excluding those of natural origin, which offend the senses of sight, smell, touch, or taste.

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WAC 173-201-040 -------GENERAL CONSIDERATIONS. The following general guidelines shall be applicable to the water quality criteria and classifications set forth in WAC 173-201-020 through WAC 173-201-080 hereof:

(3) Except for the aesthetic values and acute biological shock conditions the water quality criteria herein established shall not apply:

(a) Within immediate mixing zones of a very limited size adjacent to or surrounding a wastewater discharge;

(b) In the case of total dissolved gas, when the stream flow exceeds the 10-year, 7-day average flood;

(c) In a manner contrary to the applicable conditions of a valid discharge permit.

(4) The total area and/or volume of a receiving water assigned to a mixing zone shall be as described in a valid discharge permit and limited to that which will: (a) not interfere with biological communities or populations of important species to a degree which is damaging to the ecosystem; (b) not diminish other beneficial uses disproportionately.

(5) The criteria established in WAC 173-201-030 through WAC 173-201-050 for any of the various classifications of this regulation may be modified by the director for limited periods when receiving waters fall below their assigned water quality criteria due to natural causes or if in the opinion of the director the protection of the overall public interest and welfare requires such modification.

(6) Except where the director determines that overriding considerations of the public interest will be served, wherever receiving waters of a classified area are of a higher quality than the criteria assigned for said area, the existing water quality shall consitute water quality criteria.

(7) Whenever the natural conditions are of a lower quality than the criteria assigned, the natural conditions shall constitute the water quality criteria.

(8) Due consideration will be given to the precision and accuracy of the sampling and analytical methods used in the application of the criteria.

(9) The analytical testing methods for these criteria shall be in accordance with the most recent editions of Standard Methods for the Examination of Water and Waste Water, and Methods for Chemical Analysis of Water and Wastes (EPA 16020), and other or superceding methods published or approved by the department following consultation with adjacent states and concurrence of the Environmental Protection Agency.

(10) Deleterious concentrations of radioactive materials for all classes shall be as determined by the lowest practicable concentration attainable and in no case exceed: (a) 1/3 of the values listed in WAC 402-24-220 (Column 2, Table II, Appendix A, Rules and Regulations for Radiation Protection), or (b) the 1962 U.S. Public Health Service Drinking Water Standards as revised, or (c) the Radiation Protection Guides for maximum exposure of critical human organs recommended by the former Federal Radiation Council in the case of foodstuffs harvested from waters for human consumption.

(11) Deleterious concentrations of toxic, or other nonradioactive materials shall be as determined by the department in consideration of the Report of the National Technical Advisory Committee on Water Quality Criteria, 1968, and as revised, and/or other relevant information.

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WAC 173-201-050 -------CHARACTERISTIC USES TO BE PROTECTED. The following is a noninclusive list of uses to be protected by the various classifications in fresh and marine waters:

USES	WATERCOURSE CLASSIFICATION A
FISHERIES	
Salmonid	
Migration	F M
Rearing	F M
Spawning	F
Warm Water Game Fish	
Rearing	F
Spawning	F
Other Food Fish	F M
Commercial Fishing	F M
Shellfish	M
WILDLIFE	F M
RECREATION	
Water Contact	F M
Boating and Fishing	F M
Environmental Aesthetics	F M
WATER SUPPLY	
Domestic	F
Industrial	F M
Agricultural	F
NAVIGATION	F M
LOG STORAGE AND RAFTING	F M
HYDRO-POWER	F

- - - - - - - - - - - - - - -

NEW WAC 173-201-080 -------SPECIFIC CLASSIFICATIONS. Various specific waters of the State of Washington are classified as follows:

Class A (24) Columbia River from Washington-Oregon border (river mile 309) to Grand Coulee Dam (river mile 595). Special condition from Washington-Oregon border (river mile 309) to Priest Rapids Dam (river mile 397). Temperature - water temperature shall not exceed 68°F due in part to measurable (0.5°F) increases resulting from human activities; nor shall such temperature increases, at any time, exceed $t = 110/(T-15)$; for purposes hereof, "t" represents the permissive increase and "T" represents the water temperature due to all causes combined.

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APPENDIX II.1-H

PLUTONIUM MOVEMENT IN HANFORD SOIL SYSTEMS

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II.1-H PLUTONIUM MOVEMENT IN HANFORD SOIL SYSTEMS [RPB, X.24]

The retention of plutonium by Hanford sediments is well documented for specific waste solutions and disposal areas.[1-18] Laboratory studies show that the bulk of the plutonium in waste solutions at near-neutral pH is removed from solution by the sediments relatively close to the disposal point.[1-4]

II.1-H.1 Plutonium in Inorganic Waste Streams

An initial investigation determined that ion exchange[5] was the plutonium removal mechanism on sediments from near-neutral to slightly acid waste solutions. A later study of the effects of pH on plutonium removal by Hanford sediments by the same author[6] indicated that removal of plutonium at pH 2.0 or higher was as a polymer or hydrolyzed species, $Pu(OH)_n^{+4-n}$. Pu (IV) polymer carries a positive charge and the final product of polymerization is $Pu(OH)_4$ or $PuO_2 \cdot xH_2O$.[19] Therefore, from about pH 1.0 to 4.0, the plutonium removal mechanism changes from principally ion exchange to principally precipitation and subsequent filtration by the sediment. The polymer becomes colloidal in size and neutral to near-neutral in charge over the pH range 9.0 to 12.0 and tends to pass readily through a sediment column.[6] The removal of plutonium from a high salt acid waste by sediments was studied.[10] Plutonium removal from a solution containing 5.4 moles per liter nitrates and 0.3 moles per liter nitric acid was poor. Organic compounds also caused the removal of plutonium by sediments to be less efficient.

The sediment-plutonium relationships in core samples from the first 2 feet of 216-Z-9 covered crib were studied.[14] At least two types of plutonium occurrences were found in 216-Z-9 sediments that received high salt, acid waste from plutonium process operations. Plutonium particles identified by X-ray diffraction tracings as PuO_2 were the most conspicuous form. The PuO_2 was filtered out of the waste solution in the first few inches of the sediment column; it probably entered 216-Z-9 as discrete PuO_2 particles.

The second type of plutonium occurrence is associated with rock fragment silicate hydrolysis caused by the highly acidic nature of the waste solutions. The second type of plutonium was originally in solution in the acid waste. The localized pH rise that occurred during the hydrolysis reaction may have caused the precipitation of the accompanying plutonium. Hydrolysis reactions were more intense at high surface area lenses of fine-grained silts in the sediment column. As a result, higher plutonium concentrations associated with the silt lenses occurred at random in the 30 feet of sediments investigated.

Plutonium mobility in sediments from 216-Z-9 covered trench was investigated.[11] Column leaching experiments of surface sediments from 216-Z-9 covered trench indicated that up to 0.1% of the plutonium could be mobilized by leaching with groundwater. However, after the initial rapid leach rate of plutonium by 13 column volumes of groundwater, plutonium movement was essentially nil. Plutonium migration into lower sediment layers then became five orders of magnitude slower than the velocity of the groundwater solution.

The depth of plutonium penetration of the sediment column beneath 216-Z-1A tile field and 216-Z-12 covered trench disposal sites was studied.[13] In the 216-Z-1A tile field that received a limited volume of high salt acid waste, the grams of Pu per gram of sediment varied from 12.4×10^{-8} at 10 feet below the top of the sediment column to 0.6×10^{-8} at 18 feet. No detectable plutonium, on the other hand, could be found on the sediments below 8 feet in 216-Z-12 covered trench which received neutralized plutonium-bearing waste.

II.1-H.2 Plutonium in Organic Waste Streams

Reactions with Hanford sediments of organic waste containing plutonium were studied.[12] Percolation of organics through the sediments had little effect on soil permeability for subsequent filtration of high salt aqueous waste. Sediments removed little or none of the ^{239}Pu from wastes of dibutylbutyl-phosphonate or di-(2-ethylhexyl) phosphoric acid but essentially all of the ^{239}Pu was removed from fabrication oil, a mixture of lard oil and carbon tetrachloride used as a machining lubricant. None of the organics except di-(2-ethylhexyl) phosphoric acid plus tributylphosphate in normal paraffin hydrocarbons (a commercial mixture of straight chain hydrocarbons) and hydroxyacetic acid removed ^{239}Pu from the sediments in large quantities. Approximately 30% of the adsorbed plutonium was removed from a sediment column by the D2EHPA-TBP mixture. Hydroxyacetic acid removed all of the adsorbed ^{239}Pu at rates proportional to hydroxyacetic acid solution strengths.

II.1-H.3 Plutonium Movement by Plant Growth

Studies[9] have shown that only small amounts of ^{239}Pu are translocated from the sediments to plant leaves during plant growth. Leaf to soil ratio for ^{239}Pu was about 0.0001 on the average for barley grown on milville silt loam, Cinebar silt loam and Ephrata fine sandy loam. Table II.1-H-1 shows the distribution of plutonium found in barley grown in several concentrations of plutonium in soil. The shoots to soil ratios ranged from 0.54×10^{-4} to 1.3×10^{-4} for soil concentrations of 10 μCi/g to 0.05 μCi/g, respectively.[17,18]

TABLE II.1-H-1

INFLUENCE OF SOIL PLUTONIUM CONCENTRATION ON UPTAKE AND DISTRIBUTION OF PLUTONIUM IN BARLEY SHOOTS AND ROOTS

Soil Plutonium Concentration	Plant Uptake of Plutonium(a): Shoots		Roots	
	Concentration, 10^{-4}μCi/g	Concentration Factor(b) $\times 10^4$	Concentration, 10^{-4}μCi/g	Concentration Factor(b) $\times 10^4$
μCi/g				
10.00	5.4	0.54	36	3.6
0.50	0.95	1.9	3.0	6.0
0.05	0.07	1.3	0.55	11.0

(a) Based on oven-dry (60°C) weight.
(b) (μCi Pu/g oven-dry plant tissue/μCi Pu/g oven-dry soil).

To provide a basis for evaluation of the microbial influences on plutonium tranformations in soil and as a first phase in isolation of plutonium resistant organisms, the effect of soil plutonium concentration on the soil microflora was measured as a function of changes in microbial types and numbers and soil respiration rate. Plutonium did not generally affect the rate of growth of soil microflora but decreased the total numbers of all classes of microorganisms at levels as low as 0.05 μCi/g or 1 μg/g. The fungi were the exception, differing from the controls only at a plutonium concentration of 10 μCi/g or 180 μg/g.

To provide a preliminary assessment of the potential for microbial alteration of plutonium solubility in soil under aerobic conditions, soils sterilized by gamma irradiation were treated, incubated and microbial types and numbers and soil respiration rate measured for in the same general manner as described for the nonsterile soil.

At intervals during incubation over a 30 day period, sterile and nonsterile soils, which contained 10 μCi plutonium/g of soil, were sampled, and the subsamples (1 g) were suspended in 1 liter of distilled water. Plutonium solubility in the nonsterile soil increased by a factor of 3 with incubation time to 14 days and remained significantly higher than the sterile soil during the incubation period. This increase generally followed the accumulative carbon dioxide curve, with maximum solubility assured at the end of logarithmic growth for all classes of organisms. The concentration of plutonium in the 0.01 μ filtrate, which represented a plutonium level less than 0.2% of that applied, did not change significantly with treatment.

At least under the conditions of the study, the evidence strongly suggests that the solubility of plutonium in soil is influenced by the activity of the soil microflora. This effect is closely related to soil respiration rate. Although the mechanism of this effect cannot be clearly defined at this time, several possibilities exist, including: 1) the direct alteration of plutonium form such as modification of the plutonium polymer or plutonium valence state; 2) the production of organic acids which may form complexes with plutonium; or 3) the alteration of the pH of the soil solution in the immediate vicinity of the colloid without measurable effects on the overall soil pH.

Investigations are presently underway to determine the mechanism of this effect. Resistant microorganisms are being isolated using enrichment techniques for further study of the chemical form of the metal in microbial cells and exocellular media. Furthermore, investigations are underway to characterize the form of plutonium in plants and of soluble plutonium in the soil.

Increased water solubility of plutonium following incubation of plutonium containing soils at optimum conditions for microbial activity may be expected to increase plutonium uptake by plants provided the plant is not able to exclude the increased metal.

Regardless of the mechanism for increased plutonium uptake at the lower soil concentration levels, most estimates of plutonium hazard to man are based on concentration factors of approximately 5×10^{-5}, derived largely from studies at the higher soil plutonium levels. Therefore, the results suggest that new emphasis be placed on determination of plutonium uptake by plants from soils containing plutonium at environmental levels and re-evaluation of previously accepted concentration factors.

The plutonium levels in barley roots were factors of 3 to 8 greater than in the barley shoots, depending upon soil plutonium concentration. Autoradiographs showed that in contrast to the shoots where plutonium was concentrated near the crown, plutonium was distributed over the entire length of the root. In the system employed, plutonium was not added to the nutrient solution in which the roots were grown nor was plutonium detected in the nutrient media. Thus, the plutonium in the roots originated from the soil and was translocated downward from the soil in the root system. Furthermore, the lack of detectable quantities of plutonium in the nutrient solution suggests that plutonium was bound tightly in the root tissue. The implications of these findings are also important in terms of evaluation of plutonium hazards in the environment because 1) root crops directly consumed by man may contain plutonium at levels exceeding those found in other crop plants in which the tops are consumed; 2) plutonium, considered largely immobile in soil, may be distributed much further down the soil profile than previously expected due to its mobility in the plant root system; and 3) decomposing roots may represent a significant source of plutonium of different solubility and plant availability than the plutonium directly entering the soil environment.

In order to provide a better understanding of the fate and hazard of plutonium in the environment, research must be directed toward determination of 1) the uptake of plutonium by a broad range of plants from representative soil types containing plutonium at environmental levels, with emphasis on root crops; 2) the potential for recycling of plutonium present in plant roots; and 3) the form and behavior of plutonium in soils and plants. Research studies in these areas are currently in progress.

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APPENDIX II.3-A

DEMOGRAPHIC AND ARCHAEOLOGICAL DATA

APPENDIX II.3-A

DEMOGRAPHIC AND ARCHAEOLOGICAL DATA

APPENDIX II.3-A, Part 1

Population Projections with Geographical Distributions within 50-Mile Radius of

- Hanford Meteorological Station
- 100-N Area
- 300 Area

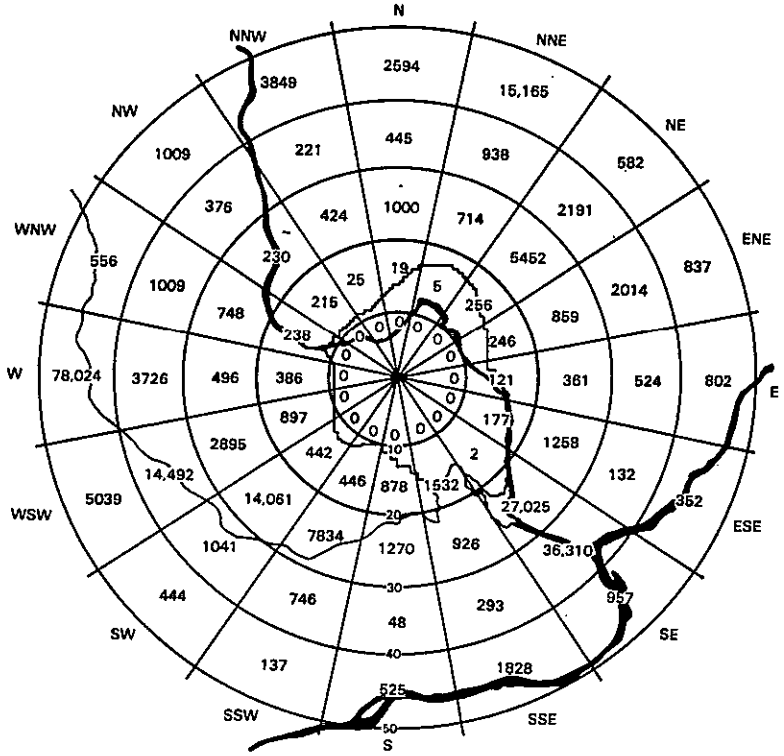

FIGURE II.3-A-1 ESTIMATED GEOGRAPHIC DISTRIBUTION OF THE 1973 POPULATION (249,000) WITHIN A 50-MILE RADIUS OF THE HANFORD METEOROLOGICAL STATION

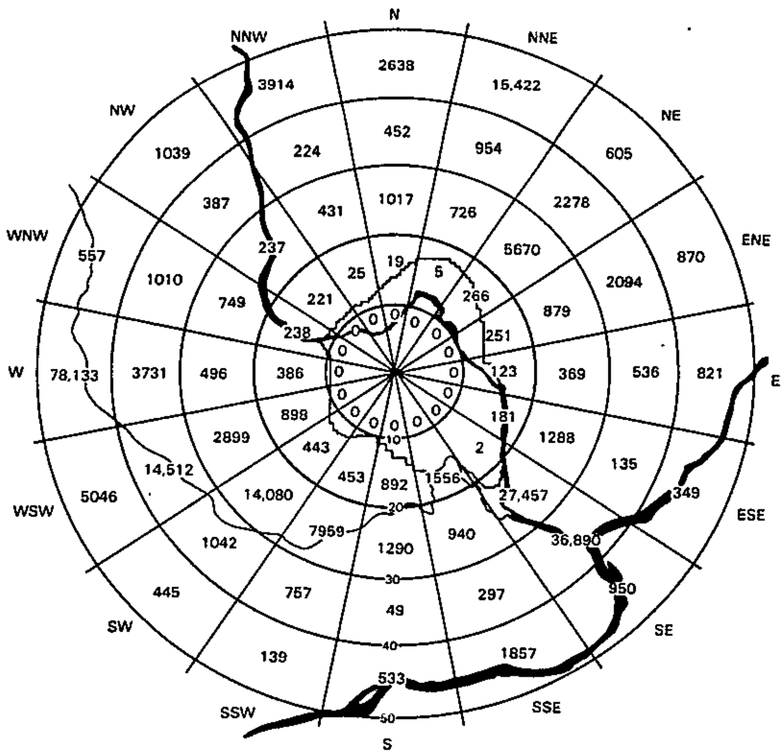

FIGURE II.3-A-2 ESTIMATED GEOGRAPHIC DISTRIBUTION OF THE 1977 POPULATION (251,000) WITHIN A 50-MILE RADIUS OF THE HANFORD METEOROLOGICAL STATION

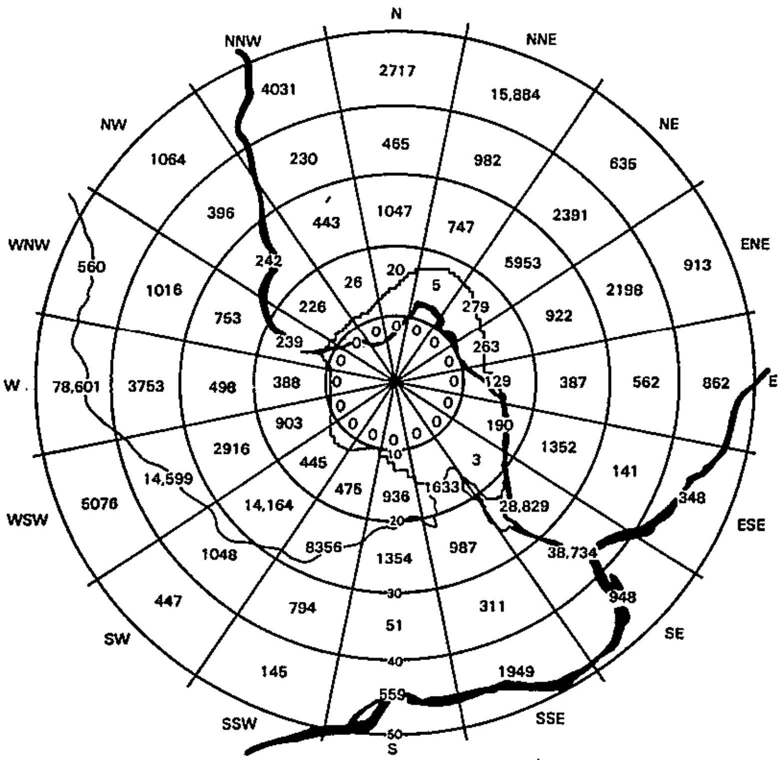

FIGURE II.3-A-3 ESTIMATED GEOGRAPHIC DISTRIBUTION OF THE 1981 POPULATION (258,000) WITHIN A 50-MILE RADIUS OF THE HANFORD METEOROLOGICAL STATION

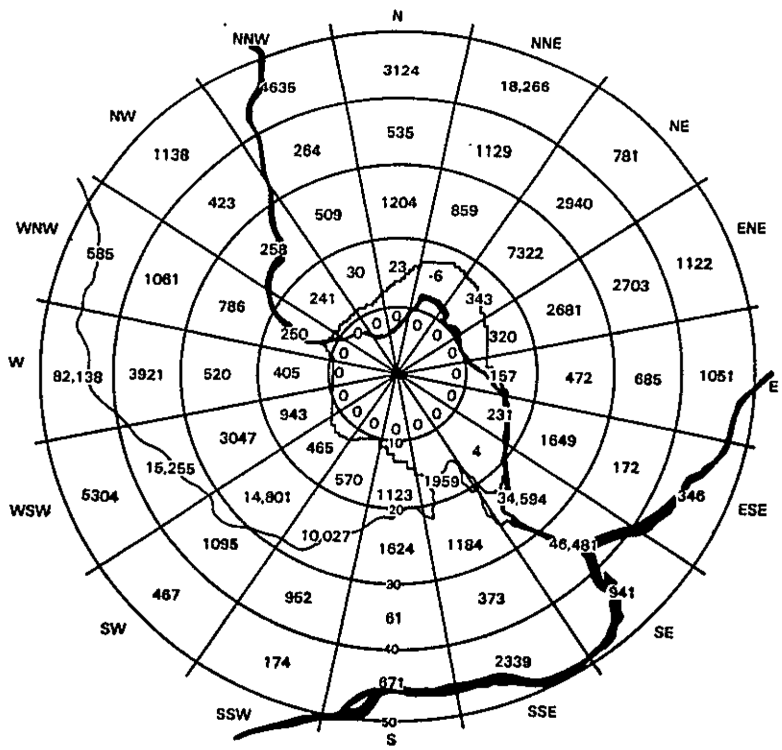

FIGURE II.3-A-4 ESTIMATED GEOGRAPHIC DISTRIBUTION OF THE 2000 POPULATION (288,000) WITHIN A 50-MILE RADIUS OF THE HANFORD METEOROLOGICAL STATION

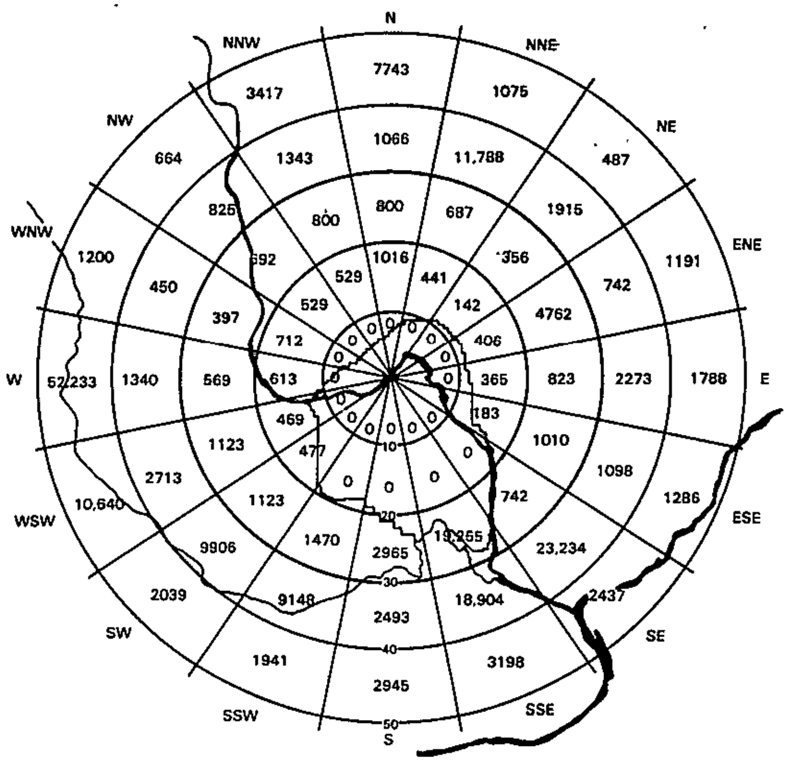

FIGURE II.3-A-5 ESTIMATED GEOGRAPHIC DISTRIBUTION OF THE 1973 POPULATION (227,000) WITHIN A 50-MILE RADIUS OF THE 100-N AREA

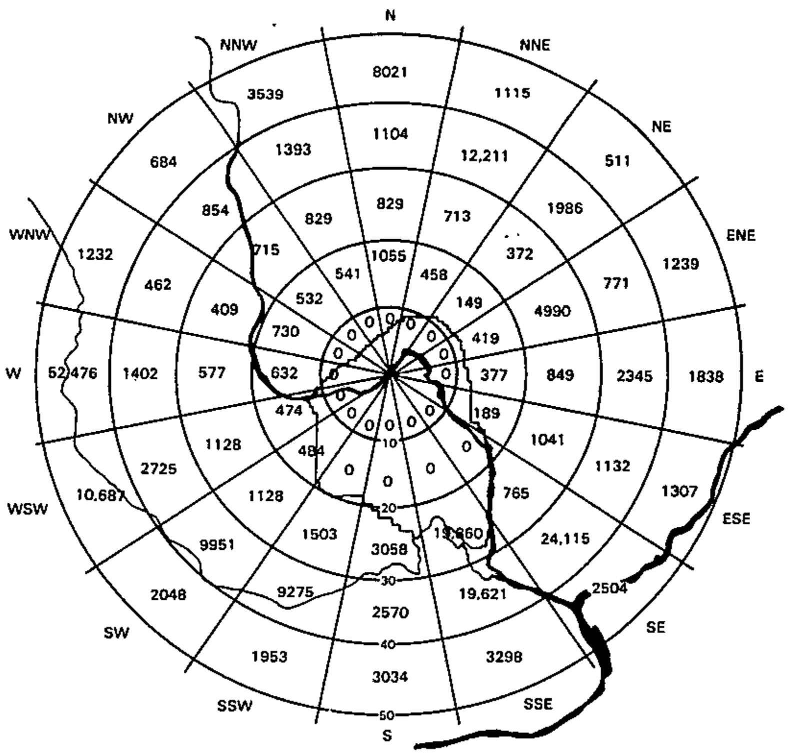

FIGURE II.3-A-6 ESTIMATED GEOGRAPHIC DISTRIBUTION OF THE 1977 POPULATION (232,000) WITHIN A 50-MILE RADIUS OF THE 100-N AREA

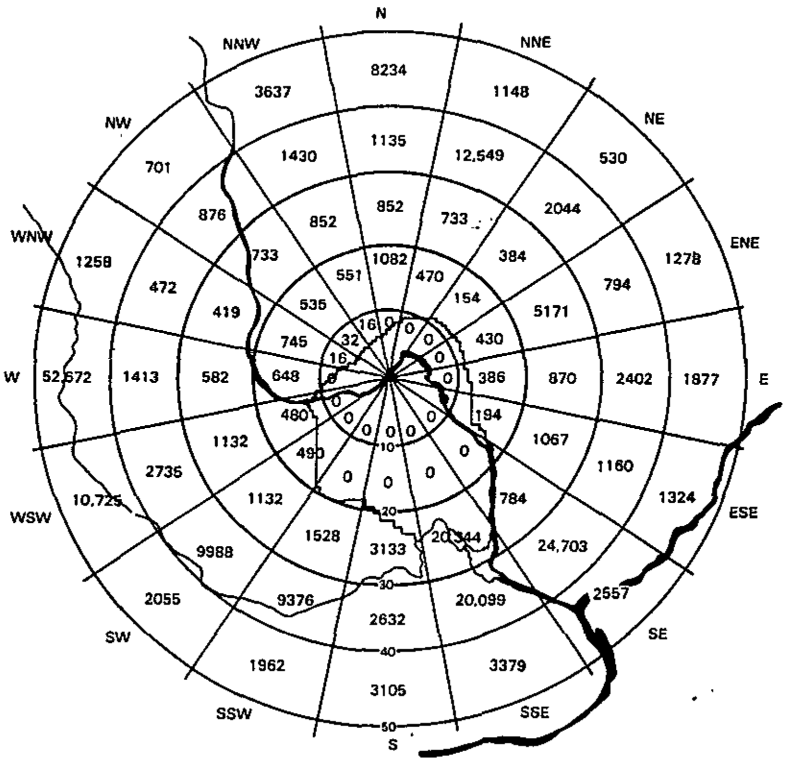

FIGURE II.3-A-7 ESTIMATED GEOGRAPHIC DISTRIBUTION OF THE 1981 POPULATION (236,000) WITHIN A 50-MILE RADIUS OF THE 100-N AREA

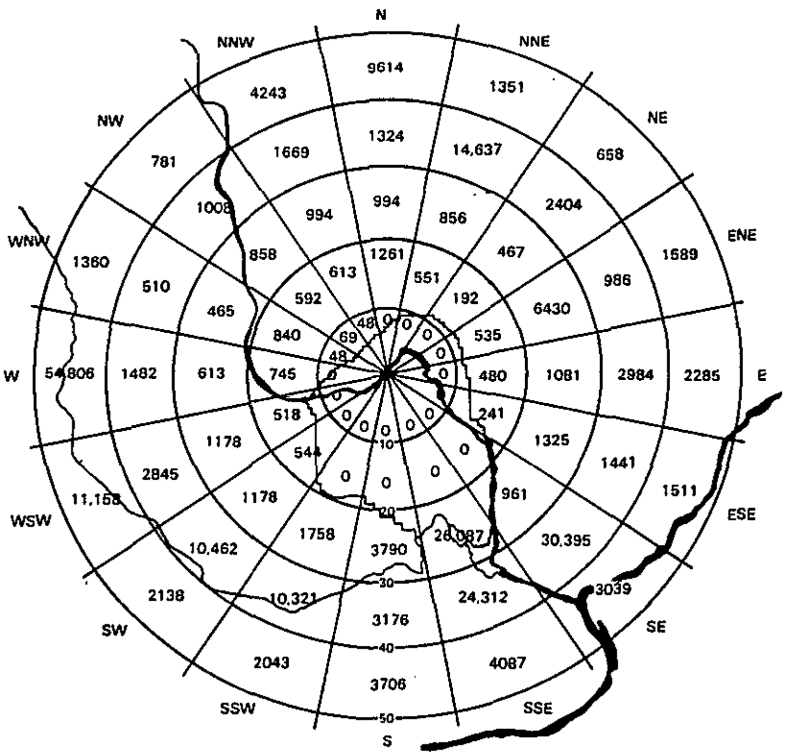

FIGURE II.3-A-8 ESTIMATED GEOGRAPHIC DISTRIBUTION OF THE 2000 POPULATION (271,000) WITHIN A 50-MILE RADIUS OF THE 100-N AREA

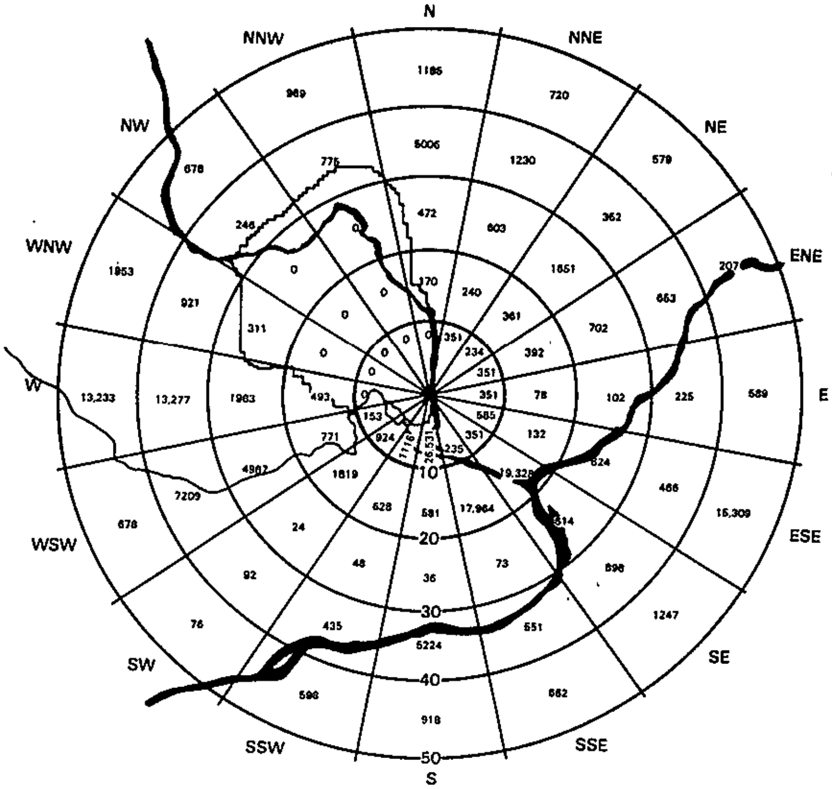

FIGURE II.3-A-9 ESTIMATED GEOGRAPHIC DISTRIBUTION OF THE 1973 POPULATION (164,000) WITHIN A 50-MILE RADIUS OF THE 300 AREA

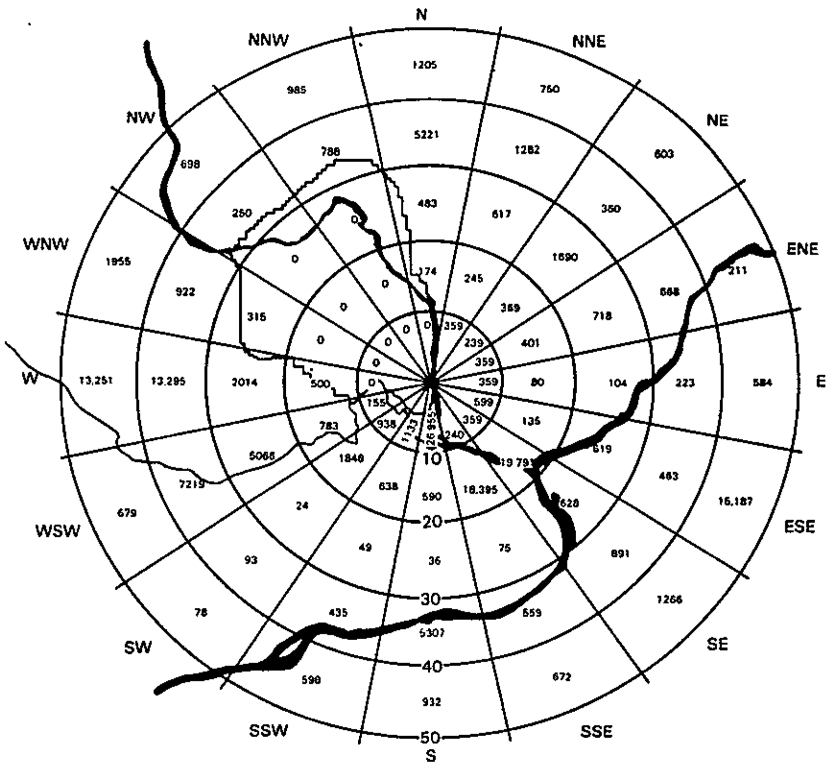

FIGURE II.3-A-10 ESTIMATED GEOGRAPHIC DISTRIBUTION OF THE 1977 POPULATION (166,000) WITHIN A 50-MILE RADIUS OF THE 300 AREA

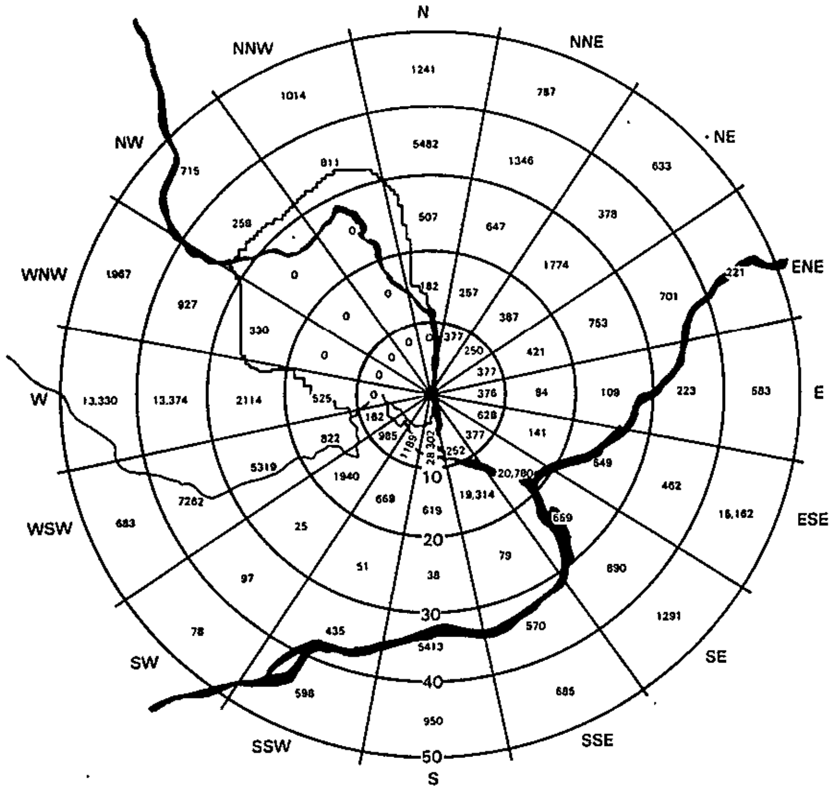

FIGURE II.3-A-11 ESTIMATED GEOGRAPHIC DISTRIBUTION OF THE 1981 POPULATION (171,000) WITHIN A 50-MILE RADIUS OF THE 300 AREA

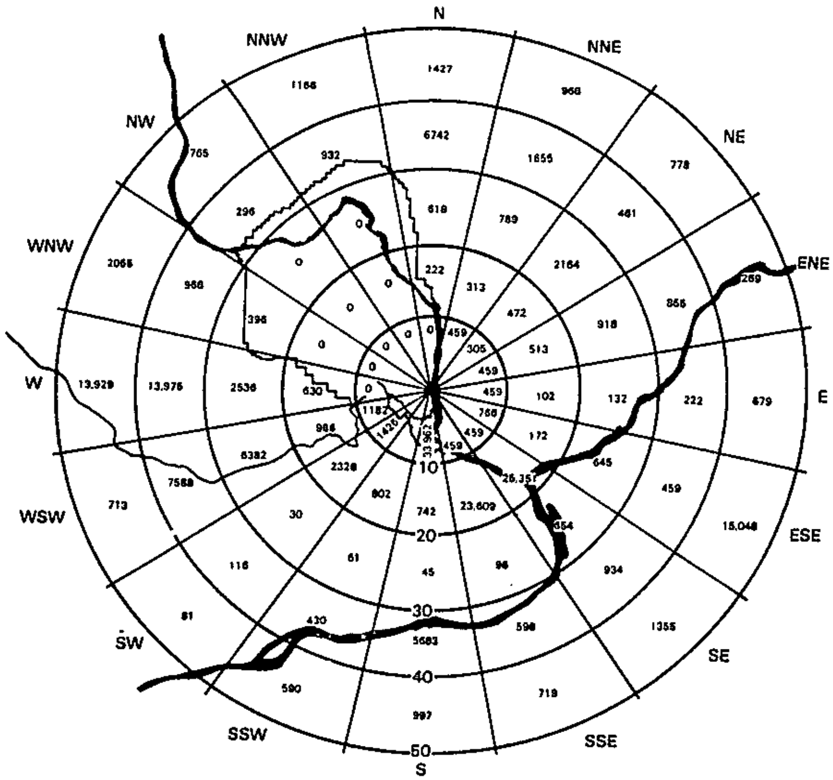

FIGURE II.3-A-12 ESTIMATED GEOGRAPHIC DISTRIBUTION OF THE 2000 POPULATION (195,000) WITHIN A 50-MILE RADIUS OF THE 300 AREA

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APPENDIX II.3-A, Part 2

Estimated Water Usage for 50 Miles Downstream from the 100-N Area (1970)

APPENDIX II.3-A, Part 2

ESTIMATED WATER USAGE FOR 50 MILES DOWNSTREAM FROM THE 100-N AREA (1970)

User	Annual Quantity in Acre-ft	Source[a]	Use[b]
USBR	20	G	D
Bailie	200	S	I
Lloyd	240	S	I
AEC	4,500	S	C
AEC	4,380	S	C
AEC	4,500	S	C
Herman	16	G	I,D
Skidmore	6	G	I
City of Richland	67,242	S	I,D,M,C
City of Richland	6,400	G	D,M,C
Battelle	880	S	I
University of Washington	1,250	S	I
Sloat	2	S	I
State	9	G	D
Pasco	51	S	C
Petty	96	S	I
Ketchersid	332	S	I
Rogers	1,419	G	C
Clark	53	G	I,D
Jacobsen	24	G	I,D
County, Franklin	18,300	S	I
Smith	10	G	D
Mocear	226	G	I,D
Stout	60	G	I
Driver	3	G	I,D
Young	18	G	I,D
Harris	12	G	I,D
Maxson	120	G	I,D
Grove	11	G	I,D
Columbia Basin College	171	G	I
Kahlen	50	G	I,D
Wirth	50	G	I,D
Collier Carbon	113	G	C
Allied	3	S	C
Henchel	3	S	I
Mullen	96	G	I
Lanning	136	G	I
Pride	24	G	D
Gustafson	60	G	I
Laird	80	G	I
Seidle	100	G	I
Howard	80	G	I
Rush	300	G	I
Blair	137	G	D
Lampon	7	G	I
Blair	140	G	I
Valdez	28	G	I
School	184	G	I,D
Slocumb	7	G	I,D
Eggers	100	G	I
Tink	50	G	D
Chevron	13,040	G	C
Philiips	323	S	C
Rick	11	G	I,D
Blair	40	G	I,D
Sandvik	293	G	C
Calhoun	45	G	I,D
Tomas	376	G	I,D
Carnahan	34	G	I
Bennett	60	G	I
Phillips	158	G	I
MacRoberts	26	G	I
Brown	94	G	I,D
USCE	24	G	I,D
Kennewick	5,600	G	M
Kennewick	9,600	G	M
State	1,693	G	I,D
Dietrick	72	G	I
USDI	115	G	C
Bumgarner	8	C	D
Hospital	20	G	I,D
Pasco	7,000	S	M
Pasco	209	G	M
Columbia	2,588	G	I
Collins	12	G	I,D
Olsen	130	G	I,D
Copeland	65	G	I,D
Kloppenstein	150	G	I,D
Clancy	70	G	I,D
Briston	23	G	I
Johnson	50	G	I
Stromme	90	G	I,D
Stromme	40	G	I
County, Franklin	18,300	S	I
Philip	12	G	I,D
Philip	12	G	I,D
Kuffel	8	G	I,D
Olson	7	G	I,D
Rogers	2,838	G	C
Rogers	490	G	C
Washington State	3,349	G	I,D
Columbia	915	G	I
Pasco	300	G	I,D
NPRY	108	G	C
Sea. Hard.	116	G	I,D,C
Close	8	G	I,D
Mudd	8	G	I
Fanning	32	G	I,D
Frontier	127	G	I,D,C
Columbia	845	G	I
Columbia	839	G	I
Columbia	719	G	I
Livestock	120	G	I
Kennewick	3,200	G	C
Atwood	60	G	I,D
Franklin	38	G	I,D
Beauchamp	80	G	I,D
Thomas	18	G	I
Mount	19	G	I
Laird	72	G	I
Mensinger	16	G	I
Freeman	48	G	I
Corn	46	G	I,D
Gregg	36	G	I
USCE	50	G	I,D
Gen. Chem.	32	G	C
Richards	82	G	I
Columbia	2,588	G	I
Burnham	40	G	I
USFWS	684	G	I
Umbarger	320	G	I,D
Port of Walla Walla	52	G	C
Benninghaven	950	G	I,D
TOTAL	190,000		

(a) G = Well, S = Surface
(b) I = Irrigation, D = Domestic, M = Municipal, C = Commercial

APPENDIX II.3-A, Part 3

Archaeological Sites and Description

APPENDIX II.3-A, Part 3

ARCHAEOLOGICAL SITES AND DESCRIPTION

A number of archaeological sites in the Hanford Reservation area have been identified[1,2] and are described in the following table. Identification numbers were assigned by the Archaeological Research Center, Washington State University, Pullman, Washington. ERDA procedures are derived in part from policies to provide for the preservation of historic or cultural American sites, buildings, objects, structures, and antiquities of national significance as required by the Federal Antiquity Act of 1906 (16USC 431 et seq.), the Historic Sites Act of 1935 (16USC 461 et seq.), and the National Historical Preservation Act of 1966 (16USC 470 et seq.).

45BN105

This is a possible housepit site located on a sheltered bench 1.0 miles north of the old North Richland townsite. (SW 1/4 of the SE 1/4 of Sec. 11, T.10N., R.28E., W.M.).

The site consists of scattered concentrations of camp rock along the riverbank and may include as many as four or five housepits on the beach above the bank. The site is about 200 ft long and 150 ft wide.

Artifacts encountered include cobble tools and hopper mortar.

45BN106

This is an open camp site located immediately to the southeast of the 300 Area along the riverbank. (Center of Sec. 11, T.10N., R.22E., W.M.).

The site consists of scattered concentrations of camp rock, flakes, and shell. It is about 400 ft long and 150 ft wide.

Artifacts encountered include stemmed projectile points, cobble tools, and hopper mortars.

45BN145

This is an ethnographically reported camp site located on the south bank of the Columbia opposite a large island upstream from Locke Island. (NW 1/4 of Sec. 12, T.14N., R.26E., W.M.).

The site consists of three or four mat lodge depressions on a gravel bar close to water's edge. Much camp rock and many flakes are scattered around the encampment. The site was reportedly last occupied about 1915.

Artifacts encountered include cobble tools, hopper mortars, a chipped stone knife, corner-notched projectile points, and a grooved net weight.

45BN162

This is an open camp site located along the riverbank at the 300 Area. (SE 1/4 of the SW 1/4 of Sec. 11, T.10N., R.28E., W.M.).

The site consists of scattered concentrations of camp rock, flakes, and shell. It is about 600 ft long and 150 ft wide.

Artifacts encountered include cobble tools, notched pebble sinkers, grooved net weights, hopper mortars, a glass trade bead, and a military button.

45BN163

This is a possible housepit site located on the west bank of the Columbia just opposite the lower end of the island immediately upstream from the 300 area. (E 1/2 of the NW 1/4 of Sec. 2, T.10N., R.28E., W.M.).

The site consists of scattered concentrations of camp rock, flakes, shell. Several hearth areas are exposed in the bank and there are five or six oval-shaped depressions strung in a line on the bench above the bank, suggesting housepits. The site is about 400 ft long and 100 ft wide.

Artifacts encountered include cobble tools, hopper mortars, and a faceted blue-glass trade bead.

45BN164

This is an open camp site located on the southern end of the island just upstream from the 300 Area. (Center of Sec. 2, 5.10N., R.28E., W.M.).

The site consists of scattered concentrations of camp rock, flakes, and shell. It is about 250 ft long and 200 ft wide.

Artifacts encountered include cobble tools, notched pebble sinkers, and corner-notched projectile points.

45BN165

This site is a fishing station located on the west bank of the Columbia about 1.0 miles north of the 300 Area. (NE 1/4 of the SW 1/4 of Sec. 35, T.11N., R.28E., W.M.).

The site consists of concentrations of cobble tools and notched pebble sinkers. It is about 125 ft long and 30 ft wide.

45BN166

This is an open camp site located on the west bank of the Columbia about 1.7 miles north of the 300 Area. (SW 1/4 of the SE 1/4 of Sec. 26, and the W 1/2 of the NE 1/4 of Sec. 35, T.11N., R.28E., W.M.).

The site consists of scattered concentrations of camp rock. Several hearth areas are eroding out of the bank. The site is about 300 ft long and 75 ft wide.

Artifacts encountered include cobble tools and a grooved net weight.

45BN167

This is an open camp site located on the west bank of the Columbia about 2.1 miles north of the 300 Area. (SW 1/4 of the NE 1/4 of Sec. 26, T.11N., R.28E., W.M.).

The site consists of concentrations of camp rock, flakes, and shell. Hearth areas are eroding out of the bank and it is possible that there are some filled-in housepits on the bench above the bank. The site is about 350 ft long and 100 ft wide.

Artifacts encountered include cobble tools, notched pebble sinkers, hopper mortars, a contracted-stemmed projectile point, and a blue-glass trade bead.

45BN168

This is a housepit site located about 100 yd south of the lower end of Wooded Island on the west bank of the Columbia, or approximately 2.4 miles north of the 300 Area. (NW 1/4 of the NE 1/4 of Sec. 26, T.11N., R.28E., W.M.).

The site consists of four or five housepit depressions on a bench overlooking the river. It is about 100 ft long and 50 ft wide.

No artifacts were encountered.

45BN169

This is a housepit site located on a bench on the west bank of the Columbia about 0.3 miles northeast of the Benton Substation. (NW 1/4 of the NE 1/4 of Sec. 11, T.11N., R.28E., W.M.).

The site consists of 8 to 10 housepits and shows scattered concentrations of camp rock, flakes, and shell at the base of the riverbank. It is 200 ft long and 150 ft wide.

No artifacts were encountered.

45BN170

This is an open camp site located at Rattlesnake Springs, which lies at the terminus of Yakima Ridge. (SE 1/4 of Sec. 20, T.12N., R.25E., W.M.).

The site consists of scattered concentrations of camp rock and flakes. It is severely eroded by wind deflation and is superimposed upon geological units which contain at least three volcanic ashes. It is about 600 ft long and 400 ft wide. Historically, this is the site of the Perkins Massacre which took place on or about July 10, 1878.

No artifacts were encountered.

45BN171

This is an open camp site located about 0.2 miles east of Rattlesnake Springs on the north bank of Dry Creek. (Center of the SW 1/4 of Sec. 21, T.12N., R.25E., W.M.).

The site consists of small quantities of camp rock and scattered flakes. It has been severely eroded by wind deflation. The site is about 300 ft long and 150 ft wide.

Two leaf-shaped points were encountered.

45BN172

This is an open camp site located about 0.25 miles from the mouth of the Snively Canyon on the east side of the road. (NW 1/4 of the SW 1/4 of Sec. 5, T.11N., R.25E., W.M.).

The site consists of scattered camp rock and flakes. It is about 150 ft long and equally wide.

Artifacts encountered include a corner-notched projectile point.

45BN173

This is an open camp site located at the Snively Ranch. (NE 1/4 of the SW 1/4 of Sec. 8, T.11N., R.25E., W.M.).

The site consists of a few flakes, bone fragments, and some firecracked rock exposed in a bank to the southwest of the ranch house about 30 ft. It is about 50 ft long and 30 ft wide.

Artifacts encountered include a pestle and a piece of worked antler.

45BN174

This is an open camp site located on the western side of West Lake, just south of the western terminus of Gable Mountain. (SW 1/4 of the NE 1/4 of Sec. 22, T.13N., R.26E., W.M.).

The site consists of a concentration of camp rock and flakes. It has been severely eroded by wind deflation. The site is about 75 ft long and 50 ft wide.

Artifacts encountered include corner-notched and contracted-stemmed points, and a bifacially flaked cobble tool.

45BN175

This is an open camp site located at a spring close to the summit of Rattlesnake Mountain. (SE 1/4 of the SW 1/4 of Sec. 30, T.11N., R.26E., W.M.).

The site consists of scattered flakes on a rather rocky surface with a small amount of fill. The site has been largely destroyed by construction of a pumphouse and bulldozing for a road and transmission line. It is about 50 ft long and 30 ft wide.

Artifacts encountered include small stemmed and corner-notched projectile points.

45BN176

This is an ethnographically reported camp site located about 0.2 miles east of 100-H Area. (NW 1/4 of SW 1/4 of Sec. 17, T.14N., R.27E., W.M.).

The site consists of three or four mat lodge depressions on a gravel bar and a cache of belongings in an adjacent bank. Much camp rock and few flakes are scattered around the encampment. The site was last occupied about 1942.

No artifacts were encountered.

45BN178

This is an open camp site located on the west bank of the 100-F Area slough in a sand dune. (NE 1/4 of the NE 1/4 of Sec. 4, T.13N., R.27E., W.M.).

The site consists of scattered concentrations of camp rock and flakes. It is about 400 ft long and 300 ft wide.
Artifacts encountered include a corner-notched projectile point.

45FR266

This is a historic site located on the east bank of the Columbia opposite East White Bluffs townsite. (E 1/2 of Sec. 29, T.14N., R.27E., W.M.).

The site consists of scattered concentrations of camp rock, flakes, and shell. In addition, the site is of historic interest because of a small log house which was reportedly built in the 1850's and used as a blacksmith shop. The site is about 2000 ft long 500 ft wide.

Artifacts encountered include cobble tools, notched pebble sinkers, pestles, small corner-notched points, glass trade beads, and a clam shell disc bead.

45GR325

This site is a flaking floor located on the Wahluke Slope above the White Bluffs and south of State Highway 24. (N 1/2 of the NW 1/4 of Sec. 6, T.14N., R.26E., W.M.).

The site consists of scattered cores and chipping detritus. These have been exposed by wind deflation on the tops and sides of small knolls along Northern Pacific Railway right-of-way.

Artifacts encountered include cores and corner-notched projectile points.

Archaeological Localities

Gable Butte Locality

The Gable Butte locality lies a short ways to the south of 100-B and 100-K Areas. It includes area in Sections 13 and 14, T.13N., R.25E., and Sections 18, 19, and 20, T.13N., R.26E., W.M.

Several flakes and rock piles were found along the top of the ridge at the western end of the locality.

Corner-notched projectile points were encountered from this locality.

Gable Mountain Locality

The Gable Mountain Locality lies to the northeast of 200-E Area. It includes area in Sections 13, 14, 15, 22, 23, 24, T.13N., R.26E., and Sections 18, 19, 20, and 21, T.13N., R.27E., W.M.

Relander (1956:306)[3] reports that this locality was one of the principal places where Indian boys and girls were sent on their spirit quests.

A corner-notched projectile point was encountered.

The Shifting Dunes Locality

The Shifting Dunes locality lies along the west bank of the Columbia opposite Ringold Flat and the lower end of Savage Island. It includes area in Sections 8, 9, 15, 16, 17, 18, 19, 20, 21, 22, 23, 26, 27, and 28, T.12N., R.28E., W.M.

This locality evidently contains numerous small camp sites that have been deflated by wind erosion and then buried by the shifting sands.

Corner- and basal-notched projectile points were encountered.

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APPENDIX II.3-B

HANFORD GEOLOGY DATA

APPENDIX II.3-B

HANFORD GEOLOGY DATA

APPENDIX II.3-B, Part 1

Hanford Geology Data

II.3-B, Part 1 Hanford Geology Data

II.3-B.1 Geomorphology

Eastern Washington is dominated by the Columbia Basin geologic province which encompasses about 50,000 square miles of southeastern Washington and adjacent parts of Idaho and Oregon (Figure II.3-B-1). The Basin is underlain by the vast field of flood lavas of the Columbia River Basalt Group. Today those lavas and the ground surface generally dip radially inward toward the Pasco Basin, the slightly off-centered physiographic low of the larger Columbia Basin.

The Columbia, Snake, Yakima and Walla Walla rivers reflect the regional gradients, drain centripetally and join within a few miles of each other within the Pasco Basin. To the south the Columbia River exits from the Pasco Basin through Wallula Gap at an altitude of about 340 feet, then flows westward through an ever-deepening gorge until it exits from the region through the Cascade Range.

The ERDA Hanford Reservation overlies the structural low point of the Pasco Basin. The Hanford Reservation is bounded to the southwest, west and north by large anticlinal ridges that trend eastward from the Cascade Range, enter the Pasco Basin and die out within its confines. The Reservation is bounded to the east by the Columbia River and the steep and imposing, west-facing White Bluffs of the Ringold Formation. Beyond them the gently rising basaltic lava flows lead into the Palouse country of eastern Washington. To the southeast the Reservation is bounded by the confluence of the Yakima and Columbia Rivers and by the City of Richland.

The Hanford Reservation lies on the low-lying, partly dissected and modified alluvial plain of the Columbia River within the central part of the Pasco Basin. Altitudes range from a low of about 345 feet in the southeastern part of the Reservation to a high of about 800 feet in the northwest corner. Beyond the plains, the bordering White Bluffs rise to a maximum altitude of 980 feet above sea level and the anticlinal ridges to the west rise to a maximum altitude of 3,586 feet atop the crest of the Rattlesnake Hills.

The Hanford alluvial plain contains a mix of aggradational and degradational features that reflect part of the complex geological history and development (Table II.3-B-1) of the Pasco Basin, especially during the latter part of the Pleistocene and the entire Holocene epoch (approximately the last 100,000 years). The discontinuous plain, as originally formed about 18,000 to 20,000 years ago and significantly modified about 12,000 years ago, sloped from a high of perhaps 700 to 800 feet above sea level in the northwest, to about 100 feet lower in the southeast. Subsequent to the deposition of the basin fill sediments, the Columbia River shifted generally northeastward as it adjusted its base level and its grade. Estimates of its lateral rates of shift range up to a foot per year. Today relic channels, some attributable to the last flood, cross the northeast part of the reservation. In the process of eastward shifting concomitant with downcutting, several benches or terraces related to the floods were further modified. They are best displayed in the southern part of the Reservation south of the Hanford Wye road junction. There the uppermost terrace lies at an altitude of 500 to 540 feet, while the lower terrace is 100 feet lower (400 to 440 feet), with the escarpment of boundary between the two paralleling the Columbia River and about 4 to 5 miles from the river.

Subsequent to the river shift, wind action simultaneously established two sets of dunes that now cross both terraces indiscriminately. The first set forms a belt that extends from the junction of Cold and Dry Creek valleys to a point halfway to the Yakima Horn, thence east-northeastward immediately north of the Hanford Wye road junction to the Columbia River. There they form a belt 4 miles wide immediately south of the Hanford townsite to a point opposite Ringold on the east bank of the Columbia River. They evidently originated in Cold Creek Valley by deflation of the valley and wind transport of the sands to the east-northeast.

The second group of dunes focuses on the area between the Yakima Horn and North Richland, with the dunes dying out to the northwest and southwest. The dunes trend northeastward. Their eastward convergence with the more northerly belt indicates a somewhat different direction of the prevailing winds at different localities. To a large extent this is topographic control or the presence of wind gaps and anticlinal ridges in the wind's path.

Both sets of dunes evidently developed in the dry and warm climate of the Altithermal interval and have in part stabilized as a result of subsequent climatic changes. Both sets attest to some eastward migration of the Columbia River and to the lack of its presence on the Hanford Reservation in the time since dune emplacement. Otherwise the dunes would have been breached.

The eastward shift of the Columbia River evidently is continuing in the northern reaches of the Reservation. Thus, the northern reaches of the White Bluffs (north of the Hanford townsite) are being actively undercut. Landslides of up to 1 million cubic yards have occurred and will

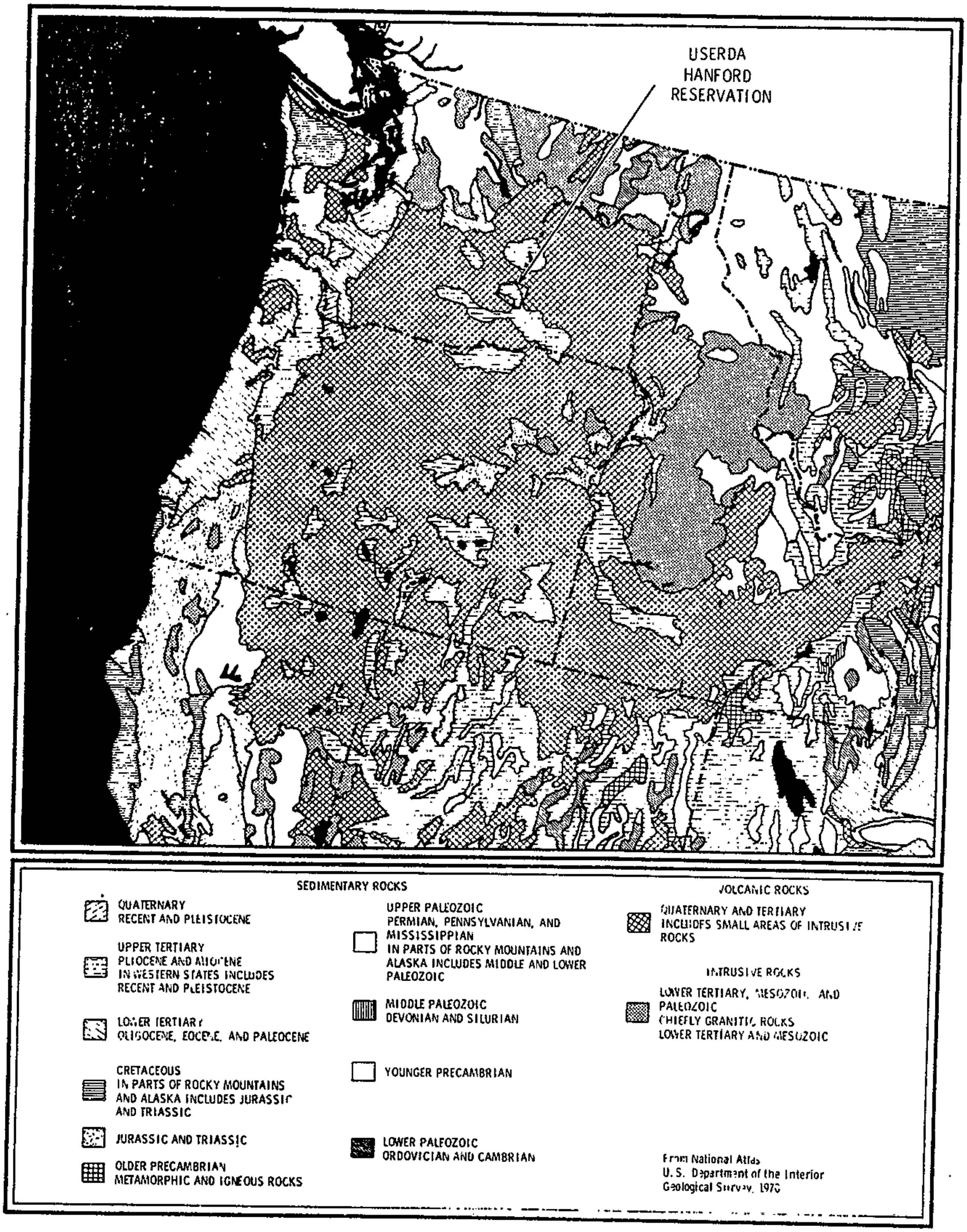


FIGURE II.3-B-1 REGIONAL GEOLOGIC MAP

TABLE II.3.B-1

GEOLOGICAL HISTORY OF PASCO BASIN

ERA	SYSTEM	SERIES	GEOLOGIC UNIT	MATERIAL
CENOZOIC	QUATERNARY	HOLOCENE	DUNES AND EOLIAN SEDIMENTS (0-40 FEET THICK)	SANDS, INCREASINGLY FINER AND QUARTZ-RICH TO THE NORTHEAST
			ALLUVIUM, COLLUVIUM, LANDSLIDES (0-100 FEET THICK)	UNSORTED RUBBLE AND DEBRIS, LOCALLY INTERFINGER WITH RINGOLD FORMATION AND PASCO GRAVELS
			PASCO GRAVELS AND THE TOUCHET BEDS (0-400 FEET THICK)	SANDS AND GRAVELS OCCURRING AS GLACIAL FLOOD DEPOSITS. COMMONLY ROUGHLY GRADED. UNCONSOLIDATED BUT HIGHLY COMPACT.
			PALOUSE SOILS (0-30 FEET THICK)	WIND-TRANSPORTED AND DEPOSITED SILT, LOCALLY WEATHERED TO CLAY
		PLEISTOCENE	RINGOLD FORMATION (0-1200 FEET THICK)	WELL-BEDDED FLUVIAL AND FLOOD-PLAIN SILTS, SANDS AND GRAVEL. POORLY SORTED, COMPACT BUT VARIABLY CEMENTED. BASAL PORTION LARGELY SILT AND CLAY OF HIGHLY VARIABLE THICKNESS. REMAINDER OF FORMATION IS INTERBEDDED GRAVEL, SAND AND SILT. GENTLY DEFORMED.
	TERTIARY	PLIOCENE	ELLENSBURG (20-200 FEET THICK) FORMATION	VOLCANICLASTIC ROCKS AND THEIR WEATHERING PRODUCTS, LARGELY CLAYS. GRADES INTO AND INTERFINGERS WITH RINGOLD FORMATION SEDIMENTS.
		MIOCENE	COLUMBIA RIVER BASALT GROUP PROB. 12,000 FT THICK: YAKIMA BASALT FORMATION (PROB. 2500 FEET THICK)	BASALTIC LAVAS WITH INTERBEDDED STREAM SEDIMENTS IN UPPER PART, LOCALLY FOLDED AND FAULTED.
			PICTURE GORGE FORMATION EQUIVALENT (?) (PROB. 1500 FEET THICK)	BASALTIC LAVAS
		OLIGOCENE	?	BASALTIC LAVAS POSSIBLY COMPARABLE TO THE TEANAWAY BASALTS
		EOCENE		PROBABLY SANDSTONES COMPARABLE TO THE SWAUK AND ROSLYN FORMATIONS
		PALEOCENE	? ?	
MESOZOIC			ROCKS OF UNCERTAIN AGE, TYPE AND STRUCTURE	PROBABLY METASEDIMENTS AND METAVOLCANICS INTRUDED BY GRANITIC ROCKS

recur as the bluffs are oversteepened. The addition of large volumes of irrigation waste waters from the Columbia Basin Irrigation Project to ground near the crest of the Bluffs increases the potential of such slides.

II.3-B.2 Soils

Eastern Washington, in the rain-shadow of the Cascade Mountains, has experienced a continuously semi-arid to arid climate for nearly 12,000 years. Most of the Hanford Reservation is underlain by generally coarse-grained sediments[1] deposited by several glacial floods. The surficial sediments generally were ineffectually weathered and only locally show the A, B and C soil horizons developing from the regolith, or the organic matter to distinquish true soils from their parent materials. Consequently, a working definition of most Hanford soils includes the materials within the root zone of the native perennial plants. This is a variable depth value depending on the plant species.

All the materials overlying basalt bedrock have at least some physical properties that generally are identified with soils in an engineering sense. That concept corresponds to the pedologist's or geologist's definition of regolith. Most of those materials also have geologic properties such as formation identity, stratigraphic continuity, weak to moderate induration and coherence, and a physical origin that permits their description in geologic terms.

Most of the Hanford Reservation is underlain by sediments laid down by the glacial Lake Missoula floods, particularly of 18,000 to 20,000 years ago and about 12,000 years ago. Those sediments, at or near the ground surface, range from coarse boulder and cobble gravel in the extreme northern reaches of the Hanford Reservation to sandy cobble to granule gravels in the central part of the Reservation to coarse sands in the southern part. Adjacent to the Yakima and Rattlesnake Hills the sediments grade into silts and fine sands. The distribution reflects the velocity of the flood waters depositing the sediments: the greatest velocities where the floods debouched from the Columbia River gorge upstream from Hanford; less where the flood waters spread out in the Pasco Basin; and least in the lee of ridges and with the shallow waters adjacent to the bordering mountain masses.

As a result of the semi-arid to arid environment that prevailed for at least 12,000 years, the entire Reservation was blanketed by at least a thin veneer of wind-blown (eolian) sediments. These were derived largely from the flood deposits, most of it locally but some from as far as the lower Yakima and Columbia River valleys upwind (southwest) of the Hanford Reservation. The eolian sediments thus range from very fine sands and silts that in some places blanket coarse gravels and basalt bedrock, to coarse sands that were moved only short distances and can scarcely be distinguished from the parent materials.

Generally, true soil profiles developed only where fine-grained and poorly drained sediments prevail, as in Cold Creek Valley. There, under the prevailing conditions, weathering is more effective than elsewhere and true A, B and C horizons develop from the regolith.

The eolian sediments not only variably blanket the Hanford Reservation from negligible thicknesses to 50 feet or more, in the case of live dunes, but the eolian silts locally have sifted into the fluvial sands and gravels to depths up to 5 feet. This decreases the ground's infiltration capacity. When that condition combines with frozen ground, local runoff occurs.

Numerous dunes and dune features prevail on site. Incorporation of the Mount Mazama ash bed in some now stabilized dunes indicates a period of dune formation 6000 to 7000 years ago during the Altithermal interval. Subsequent climatic changes are indicated that stabilized the dunes. South of the Hanford townsite, and elsewhere where the vegetal cover was destroyed in road cuts or burned areas, active dune movement is again underway.

II.3-B.3 The Basement Rocks

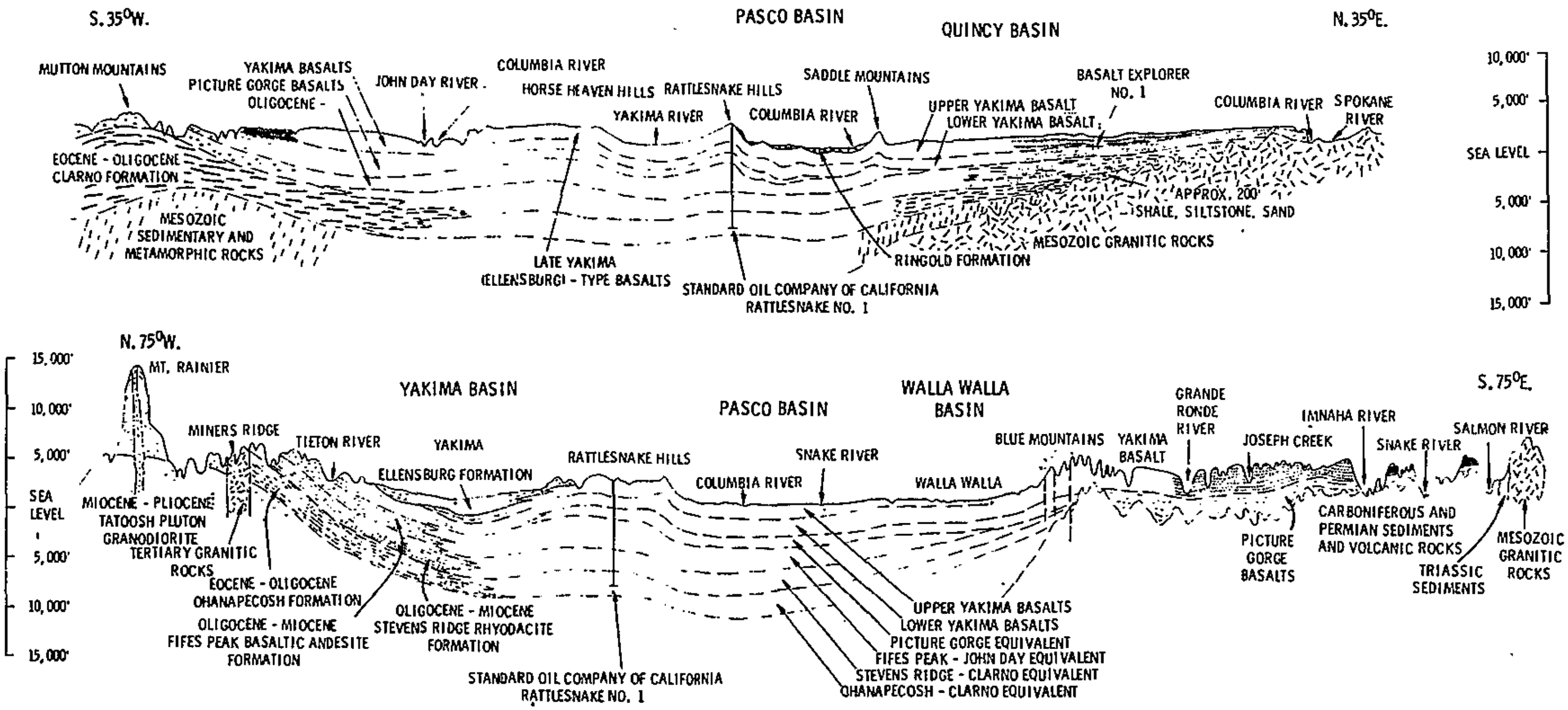
The basement rocks, those underlying the basaltic lava flows, are of uncertain composition. Certain rock types can be projected from the margins of the Columbia Basin 100 to 150 miles away, and certain prebasalt rocks can be logically inferred from the known general geologic history of the region. On these bases, and from data from the Basalt Explorer Well near Odessa, Washington, sandstones and shales comparable to the Swauk Formation of the Blewett and Swauk Pass areas of Washington may lie beneath the region. Beneath them are probably granitic rocks comparable to those in Okanogan Highlands, the Snoqualmie Pass area of the Cascade range, the Moscow Basin, Idaho, the base of the Basalt Explorer Well, and parts of the core of the Blue Mountains, Oregon.[2] Granite rocks there were intruded into largely Paleozoic and early Mesozoic metavolcanic and metasedimentary rocks whose equivalents perhaps occur beneath the Pasco Basin. Alternatively, a still thicker basalt section is possible.

II.3-B.4 The Columbia River Basalt Group

The Columbia Basalt Plateau is one of the world's greatest continental accumulations of basaltic lava flows. The total area covered is estimated at 250,000 to 300,000 square miles and comprises more than 100,000 cubic miles of lava. In the 50,000 square miles of Columbia Basin probably more than 60,000 cubic miles of lava have accumulated (Figure II.3-B-2).

The northern part of the Columbia Basin centers around the Pasco Basin, the topographic and structural low point of the Columbia Plateau area. In 1957 and 1958, the Standard Oil Company of California drilled an exploratory and stratigraphic test well (Rattlesnake No. 1) in the Pasco Basin to a depth of 10,655 ft, still in basalt. The well was reopened and relogged in 1968.[3] Current estimates are that the sequence is at least 12,000 feet thick. Other data indicate a probably orderly accumulation of more than 100 basalt flows, emitted concomitantly with the subsidence of the basin. If the oldest flows are Eocene in age as has been suggested, roughly 50 million years were available for emission of the complete sequence up to the about 8 million years age of the youngest flow. An average rate of emission then is roughly one flow per 500,000 years.

No other comparably deep wells have been drilled within the Pasco Basin or its periphery. Within the Pasco Basin, four deep wells and core holes were drilled to depths of 5661, 3540, 5002 and 4766 feet.[4] Above those depths, the data on the nature and character of the basalt sequence increase rapidly as the result of available outcrops and many wells drilled for geologic information and for water supply purposes.



SOURCES: GEOLOGIC MAP OF WASHINGTON, 1961
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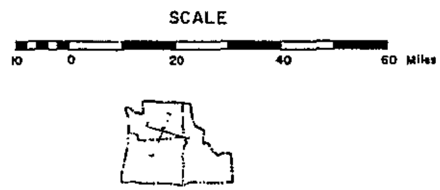

FIGURE II.3-B-2 GEOLOGIC CROSS SECTIONS OF COLUMBIA RIVER BASALT PLATEAU

The basalt sequence tentatively is divided into a series of possible formational units. The divisions are based on: 1) identified, evidently significant, changes in the chemistry of the basalts, 2) estimated ages based upon floral assemblages from pollen in coal beds in the Rattlesnake No. 1 well and 3) two initial potassium-argon age dates on basalts.[6] The very limited data can result in numerous interpretations, of which Figure II.3-B-2[6] is one. Unpublished and largely unavailable data will, when evaluated, result in increasing detail and a corresponding improvement in the interpretation.

The sources of extrusion of the early flows are unknown. All appear to be the plateau type of basalt, emitted from fissures by quiet extrusions.[4] Various dike swarms are known that may have been sources, but none are demonstrated as sources of the early flows. One possibility is the Teanaway dike swarm in the Mount Stuart area, Washington. Within the upper 1000 feet of the sequence, sufficient data are available to indicate that most of the flows in the western part of the plateau were moving between north and west when emplaced.[5] Progressively upward in the section, the evidence increasingly indicates that dike swarms in extreme northeastern Oregon were the vents for some of the flows. One vent for one or more flows lies in eastern-most Washington, another, feeding at least the youngest recognized flow, is at Ice Harbor Dam on the lower Snake River.[4] The presence of that many sources suggests that more may be present, perhaps buried by later flows beneath the Pasco Basin.

The later basalt flows generally advanced northwestward across the Pasco Basin. They pinch out in an offlap relationship to the plateau margins, the effect of the continuing subsidence and resulting opposed gradient. Many flows divided into flow units, whereby separate tongues, gushes or spurts of lava emerged from the main flow.

II.3-B.5 The Ellensburg Formation

Within the upper part of the basalt sequence, sedimentary material are increasingly important upward, beginning with the Vantage sandstone. These include tuffs and tuffaceous sediments of many kinds, in part now altered to clays. Virtually every basalt flow above the Vantage sandstone horizon is capped, at one site or another, by stream-deposited sediments. Their extent and thickness generally increase upward in the section. The lower beds tend toward rock types common to the Okanogan Highlands, southern British Columbia and the north Cascades. The upper beds show an increasing preponderance of volcanic debris referred to as the Ellensburg Formation.

About 15 million years ago, the ancestral Columbia River was crossing central Washington, laying down trains of gravels, sands, silts and clays comparable to today's Columbia River sediments. As the basalt flows advanced upon the river, they forced it westward toward Yakima. As the basin subsided, the river returned by gravity to the basin center, leaving its sediment trains as a mark of its earlier courses. East of the current course, river sediments are virtually nonexistent between basalt flows, attesting to the shifting only westward from the current basin center.[6]

In addition to the interbasalt sediments, the basalt flows themselves record the river's presence. Pillow basalts, palagonite and pillow-palagonite complexes at the bases of flows identify the former presence of water into which the flows advanced. Oftentimes they contain features indicating the direction of flow movement. In many instances the complexes with or without sedimentary interbeds are important and confined, sometimes artesian, aquifers.

Continuing subsidence resulted in maximum thickness of the basalt sequence and accumulation of the greatest number of flows in the Pasco Basin. The Pasco Basin low probably centered southwest of its current position, at least late in flow emplacement, as suggested by isopach maps of various members. Numerous thin beds of coal in the Rattlesnake No. 1 well, but not in other deep wells in comparable amounts, indicate a poorly drained area that may have been the basin low point for extended periods.

Anticlinal uplift began in the latter stages of flow emplacement. In some sites, near the Cascades, it may have been nearly 15 million years ago, roughly the time when the ancestral Columbia River first appeared in south-central Washington. Probably the ancestral Columbia River's appearance coincided with the beginning of uplift of the north Cascades which likely diverted the river from its westerly course north of the Pasco Basin.

Anticlinal uplift, together with basining, locked the ancestral Columbia River into the Pasco Basin once the ridges rose high enough that they were no longer periodically buried. The last few of the basalt flows and intervening interbeds clearly show thinning over the ridges and thickening in the valleys and pinchout where topographic highs were great enough.

Uplift progressed roughly from north to south with Umtanum Ridge and the Yakima Range rising first (or fastest) in the Pasco Basin, then the Saddle Mountains, Rattlesnake Hills, and the Horse Heaven Hills. The ancestral Columbia River, flowing southwestward from its locked-in position in the Pasco Basin across the Horse Heaven Hills, was diverted to the structural low that now is Wallula Gap. The combined uplift of the Horse Heaven Hills and Rattlesnake Hills probably caused the shift of the early Pasco Basin low point from the lower Yakima Valley to its current position.

The last four of the basalt flows (two Ice Harbor, the Elephant Mountain and Ward Gap are currently recognized) are progressively smaller and more restricted to the current basin center. The last one and probably two were emitted near Ice Harbor Dam, about 20 miles southeast of the nearest part of the Hanford Reservation. Only one of them barely reaches the Hanford Reservation and is recognized in few wells to date.[7]

The progressive decrease in indicated lateral extent (and probably volume as well) of the last four flows suggests depletion of a lava source. Comparable events must have occurred earlier, with an interval of some millions of years, prior to new flow emission.

II.3-B.6 Anticlinal Uplift and Faulting

Creation of the anticlines was dominantly by uplift, probably relating from long-term basining. Some faults may have developed as an early phase, but folding is a predominant reaction, with renewal of fault movement as an alternative. Generally the stresses that developed in deformation were relieved by slippage along the many joints and bedding planes, oftentimes on clay-rich sediments of the Ellensburg Formation, which thereby give the impression of fault gouge and major faults.[8] Folding of the basalt sequence with no superincumbent cover also resulted in sinuous fold axes at the ground surface, in some sites en echelon fold axes. At other sites cross folds complicate the structures. In all instances the divergence from single, well-defined, regular axes can be attributed to differing responses to folding of the variably-jointed, highly-layered basalt sequence. The sinuousity and en echelon nature of the fold axes and the presence of cross folds have led investigators to assume the presence of cross faults with strike slip offset up to one-third of a mile. This situation prevailed at Gable Butte and Gable Mountain on the Hanford Reservation.[9] To date, no strike-slip faults of any magnitude have been demonstrated in the Pasco Basin.

The dominant type of faulting is normal faulting, in some instances developing into graben-like structures as inferred in the Badger Canyon area and as occurs in parts of the Saddle Mountains. Thrust faults locally are significant, especially where folding has been intense. In some instances antithetic faulting developed, with portions of the uplifted anticlines downdropped.

Numerous faults are hypothesized on various bases, including topographic expression,[10] and aerial photointerpretation.[9] The most important one postulated is that along the Olympic-Wallowa Lineament, particularly the Rattlesnake-Wallula-Milton-Freewater segment and the Rattlesnake-Wallula segment.[11] Some persons have attributed gross amounts of strike-slip movement to the hypothesized Lineament fault, analogous to the San Andreas fault, but without citing specific evidence for the fault or its offset. Neither the Oregon geologic map (1969)[12] nor the Oregon gravity map[13] acknowledge or submit evidence in support of such a fault in Oregon.

Numerous signs of at least local faults are present along the various named segments of the Olympic-Wallowa Lineament. The maximum inferred stratigraphic offset on a postulated fault is 300 feet in the Badger Canyon area,[14] compared to a maximum of about 1500 feet of total stratigraphic offset by combined folding and faulting along the same segment. Thus this fault offset is less than a major part of the total offset, a situation generally prevalent in south-central Washington. In the same general area, 500 feet of stratigraphic offset, as determined from drilled wells, may be largely fault offset. In some sites along the Olympic-Wallowa Lineament, faults are spatially removed from the fold axes, hence are "primary" in origin. However, all faults are associated with the anticlinal ridges and in some instances pass longitudinally into folds. Because of their relatively minor surface offset, the faults are "secondary" in importance to folds although locally "primary" in origin.

The Rattlesnake Hills to Wallula Gap structure is an alignment of discontinuous elongate domes or doubly terminated anticlines with only local signs of faulting and none in several summit excavations. The structures between the domes, where visible or otherwise determined from the records of wells, are a sequence of flat-lying flows with no direct evidence for significant fault offset.

At the Yakima River water gap at the southeast end of the Rattlesnake Hills no folding or faulting is present. Northwestward along the north face of the Rattlesnake Hills anticline folding again becomes prominent, without identification of prominent faults or recent fault movement.[15]

The small amount of clearly demonstrable surface faulting, the minimal visible offset (compared to Basin and Range structures) and the 10 to 15 million years for the structures to develop indicate an overall low rate of diastrophism. Continuing activity is suggested, however, by apparent tilting of recent (12,000 years old) sediments at two widely separated sites,[8,16] reported cracking of the ground near Walla Walla during the Milton-Freewater earthquake of 1936 along lines paralleling the Horse Heaven Hills, and possible antithetic faulting of Ellensburg Formation beds and clastic dikes west of Prosser in the Horse Heaven Hills.

The faults along the Lineament evidently are associated with the Horse Heaven Hills anticline and similar structures rather than a major northwest trending transcurrent feature. A major Olympic-Wallula Lineament, if present as a structure, is not and has not been tectonically active since Miocene time, except possibly where its strike coincides with the strike of other structures (the Horse Heaven Hills). This is suggested by the uplift of the Blue Mountains, the Cascade Range, and the Yakima and Umtanum Ridges across the trend of the Lineament. None of those features show yet-identified evidence of fault offset attributable to movement along that Lineament and especially the gross strike-slip offset required for a major transcurrent feature.

The Rattlesnake Hills, the most prominent anticlinal ridge in southcentral Washington, consist of two main segments. The first is the eastwest trending segment that extends from the southwest corner of the Hanford Reservation to and beyond the Union Gap where it becomes Ahtanum Ridge. The second segment extends from the Yakima River water gap north of Benton City northwestward to the southwest corner of the Hanford Reservation. There it overlaps the east-west segment at the site of the Standard Oil Company of California Rattlesnake No. 1 well.[16]

Both anticlines are asymmetrical, with the steeper face on the northerly side. Much of the total range remains to be studied, but work at intervals along it has yet to disclose evidence of major faults. Indeed the structure appears to be a sequence of overlapping, in part en echelon, anticlinal folds. The site of overlap of the two segments resulted in the near symmetry of the ridge such that the Rattlesnake No. 1 well penetrated probably a full 10,000 feet of stratigraphic section, rather than passing, with depth, into the north limb of the anticline.

Attempts to explain the trend change and the termination of the Yakima and Umtanum Ridges to the north have commonly been based on north-trending faults. One version passes through Gable Butte, a second along the east end at Yakima and Umtanum Ridges. Evidence has to date been solely topographic but permissive of faults, not demanding of them.

The Yakima Ridge, instead of sharply terminating against a north-south trending fault, consists of two anticlinal ridges that plunge eastward beneath the surficial cover. The structures can be and have been traced by well drilling at intervals and by seismic, gravity and magnetometric methods. The data suggest that the structures are comparable to those of the Rattlesnake Hills continuation from the Yakima River water gap to the Horse Heaven Hills--a sequence of doubly terminated anticlines or elongate domes. Maximum relief is about 300 feet above the regional slope from the Rattlesnake Hills to the basin low.

The southernmost anticline reappears at the ground surface at the Prosser barricade, then as a line of gently folded, nonfaulted buttes that extend to and beyond West Richland as the "Horn Rapids Lineament." These buttes die out southeastward beneath the Kennewick Highlands. The more northerly of the two anticlines evidently dies out beneath the Hanford Reservation although it has been considered to cross the Columbia River as a continuous low, broad warp south of the Fast Flux Test Facility Site. The conclusion that there is a southern continuation of the low anticline was based on a well which did not penetrate to basalt. A geophysical seismic line contra-indicated the interpretation of the well log.

Umtanum Ridge, and its continuations in Gable Butte, Gable Mountain and several isolated outcrops, represents a classic case of offset, en echelon anticlinal folds oblique to the main axis of uplift. Gable Mountain consists of two anticlines, reversely asymmetrical so that opposite ends of the mountain are bounded by steep faces on opposing sides. Early workers[9] inferred a strike slip fault with offset of about two-thirds of a mile to account for the two axes. However, proponents of the concept did not explain the absence of the fault in the Rattlesnake Hills or White Bluffs where it should appear if the offset were valid. Instead, a low angle thrust fault(s) with less than 100 feet of offset occurs at the point of overlap of the two axes[11] and dies out in bedding plane shearing on both the north and south flanks of the mountain. The fault trace is covered by undisturbed flood deposits dated at more than 40,000 years old by ^{14}C methods.

The Saddle Mountains are one of the most studied anticlinal ridges in central Washington. They are significant because important faults bound the mountain to the north in its western reaches. The last discernible surface movement on the Saddle Mountain fault predates loesses dated by ^{14}C assays on organic matter to be 12,000 years old.[11]

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The beginning of anticlinal uplift, especially to the west and slightly prior to the emission of the latest basalt flows, locked the Columbia River into the Pasco Basin and halted its east-west migration. Somewhat later, uplift of the Horse Heaven Hills resulted in a continuously rising base level for the river and continued deposition of sediment.[19] Today the Ringold Formation is recognized only upstream of the Horse Heaven Hills, reflecting the control of deposition by those Hills.

The Ringold Formation arbitrarily has been divided at the type locality into a lower blue clays member, a gravel or conglomerate member, and an upper sand-silt member. The division is unrealistic for the Basin as a whole, however. Sands, silts, clays and gravels are interbedded and interlayered throughout the basin in a manner indicating a nearly continuous stream flow and continuous fluvial deposition. Even the lowermost silts and clays actually occur as a sequence of beds in different stratigraphic positions largely linked together to form a semicontinuous blanket over the basalts in the basin center. Only locally do they suggest true lake deposits. Moreover, they lap out (were never deposited) and in at least one case evidently were eroded from a basalt high. Hence local interconnection between the higher unconfined and the low confined ground waters is present. The ancestral Columbia River, based on its gravel and silt-clay distribution, generally has centered over the basin's low point. Its floodplains extended eastward and lapped upon the basaltic plains that rise to the east and northeast.

Uplift of the controlling Horse Heaven Hills continued at a pace permitting the deposition of gravel in the main stream areas. Ultimately when the river level in the Pasco Basin reached an altitude that is now 1000 feet above sea level, the Columbia River was able to maintain its channel through the structural low at Wallula Gap as rapidly as the hills rose. A lowering of base level ultimately began and is continuing today.

The age of the Ringold Formation is critical to assessing the timing of tectonic activity (anticlinal uplift and faulting) that in turn resulted in deposition of the formation. The maximum age is that of the youngest lava flows (8 million years). The youngest inferred age is middle to possibly late Pleistocene time[18] or within the last about several hundred thousand years for the uppermost beds. The latter age is invalid because of numerous lines of direct and indirect evidence, including stratigraphic, structural, sequential geologic, and paleontologic data. The official position of the U.S. Geological Survey now is that the formation is Pliocene and Pleistocene in age.[11] Probably the uppermost beds are about 1 million years old.

That tectonic deformation has continued to the current time is evidenced by warping in the Ringold Formation Stratigraphic section, decreasingly so upward, and low angle tilting of the later Touchet Beds in key sites.[8,16]

The resulting dips in the Ringold Formation beneath the plant site are low, a maximum of about 3°. The deformation has locally raised the silts and clays of the lower part of the Ringold Formation to and above the groundwater table. Groundwater flow accordingly is around these groundwater barriers in paths that confirm the presence and effectiveness of the silt-clay barriers.[21]

Stabilized water levels of the Columbia River and the presence of bordering floodplains are suggested by at least two thick beds of caliche (calcium carbonate). One caps the crest of the White Bluffs at an altitude of 900 to 1000 feet, the other lies beneath the west part of the Hanford Reservation where it caps the eroded surface of the Ringold Formation at an altitude of about 500 to 600 feet.

Adjacent to the anticlinal mountain ridges that surround the Pasco Basin, wells have disclosed coarse fanglomerates that in part interfinger with classical Ringold Formation sediments and in part overlie them.[16] The fanglomerates also pass upward into current-day alluvial fans that debouch from canyons penetrating the ridges. They attest to the fact that the Ringold Formation sediments were deposited largely subsequent to anticlinal uplift and suggest that the Rattlesnake Hills, in order to shed debris by early Ringold Formation time, must have risen earlier than the Horse Heaven Hills, also suggested by other data.

II.3-B.8 The Palouse Soils

An eolian silt (loess), in part altered to clay, and fine sand overlie part of the eroded surface of the Ringold Formation and the caliche bed beneath the western part of the Hanford Reservation.[22] This silt is considered to be the equivalent of the Palouse soils (loesses) of eastern Washington and westernmost Idaho, indicating a climate comparable to that of today, with effective wind transport and deposition of sediment.

The most significant eolian sediments lie at depths of roughly 100 feet, or from 100 to 200 feet above the groundwater table. They have no effect upon the groundwaters in the zone

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of saturation but are important in controlling the downward and lateral movement of waste waters and radionuclides above the groundwater table.

II.3-B.9 The Glacial Lake Missoula Flood Deposits

The Palouse soils, the Ringold Formation, and locally even the basalts and, the interbedded Ellensburg Formation sediments were locally eroded and truncated by a sequence of gigantic floods. These emanated from the Clark Fork Valley near Missoula, Montana, and resulted from the catastrophic release of ice-dammed glacial Lake Missoula. Smaller floods resulted from the sudden drainage of smaller, similarly glacier-dammed streams.

The earliest floods recognized in the Pasco Basin occurred at least 50,000 years ago and may be up to 100,000 years old. A ^{14}C age date on conifer bark from a less-than-oldest flood deposit on Gable Mountain provided an age of more than 40,000 years.[11] A subsequent flood of far greater magnitude appears to correlate with one in easternmost Washington dated at 18,000 to 20,000 years.[23] A still later large-scale flood is dated at about 12,000 years old on the basis of the presence of the presumed Glacier Peak ash within the uppermost beds of the deposit.[16]

The floods scoured the then-existing land surface, the Palouse Formation, and caliche from part of the surface of the Ringold Formation, deeply gouging the Ringold Formation.[23] A network of buried river channels, closely resembling the Channeled Scabland in form, now cross the central to northeastern part of the Hanford Reservation.

Basalt close to or above the current ground surface was eroded too. Gable Butte, in the direct path of the flood waters coming down the Columbia River, was stripped and the anticlines breached and eroded. Gable Mountain, farther east, was less exposed and less eroded. However, its west end pointed into the current was extensively eroded especially on the steeply-dipping south limb of the anticline. Eastward, progressively less erosion occurred until at the extreme east end a giant bar was deposited which extended toward the Hanford townsite.

Beneath 200 East Area and immediately to the north an anticline subsidiary to Gable Butte was subjected to erosion. The upwarped Ringold Formation silts and clays, the underlying sediments of the Ellensburg Formation, and locally some of the latest basalt flows were stripped away. An erosional window was created. Of significance is the fact that the erosional window provides a site where exchange of water between the confined and unconfined aquifers (separated by the Ringold Formation silt and clay beds) can occur.

The depth of erosion was sufficient that the groundwater table today throughout much of the Reservation lies within those channels. Elsewhere it commonly lies just below the Ringold Formation surface. Consequently the routes of fastest movement of groundwater and any contaminants will be in those glacial flood channels, which are filled with permeable gravels.[21]

At least two floods momentarily rose to considerable heights in the Pasco Basin when the inflow to the Basin considerably exceeded the drainage ability of Wallula Gap. The maximum height reached was about 1200 feet above sea level (roughly 800 feet above the lowest land surface at Hanford), evidently by the earlier of the two major floods. The latter flood, possibly comparable in magnitude to the first, evidently rose only to about 900 feet altitude. This may have been because Wallula Gap was reamed out by the earlier flood so that it more readily transmitted the floodwaters. Alternatively, the latter flood may have been less catastrophic, with the flood waters more spread out in time and with a lower flood crest.

The deposits of those two floods are locally distinguishable by character. Each tends to be graded, with boulder and cobble gravels in many sites forming the base of each deposit. Higher sediments in each sequence reflect the flood impoundment, with consequently finer materials deposited where currents lessened. The deposits of the earlier flood commonly include larger blocks of rock, are less well sorted, and exhibit more chaotic flood bedding.

Both floods lasted a few weeks, during which time an estimated 500 cubic miles of water passed downstream.[24] Maximum flow rates reached 9.5 to possibly 14 cubic miles per hour.[25] Ice-rafted erratics and thin silt deposits occur up to 1200 feet above sea level, but a 700 to 800 foot altitude appears to have been the maximum for basin-fill deposits. In turn this suggests that the flood crest above that altitude and to the 900 and 1200 foot altitudes was of short duration.

In addition to the vertical grading to finer sediments, a lateral grading also occurs. Boulder gravels lie within the flood deposits along the Columbia where it exits from the gorge upstream from the Hanford Reservation, decreasing in amount downstream. Southwestward, progressively farther from the main stream flood, the sediments are prevailingly finer grained (grading to cobble, pebble and granule gravels, then to very coarse to fine sands), referred to as the Pasco Gravels. Adjacent to the flanking hills, beneath Dry and Cold Creek Valleys, and up the Yakima, Walla Walla and locally the Snake rivers, the sediments are silts and fine sands known as the Touchet Beds. These beds also occur as thin blankets up to the maximum altitudes of the floods.

The Touchet Beds show evidence of quiet and shallow-water deposition with abundant rhythmic and ripple-marked bedding. Clastic dikes are characteristic within the Touchet Beds, locally within the Pasco Gravels, and less commonly in the Ringold Formation, the basalt flows and Ellensburg Formation beds. Their origin is controversial; they are related in time and probably in origin to the floods.[26,27]

The floods had additional impact. Many scarps were formed by the flood waters, and many landslides must have been induced in the basalts and the Ringold Formation by the rapidly changing lake levels (Table II.3-B-2). Persons unfamiliar with the total effect and height of the floods have concluded that some of those features reflect fault movement and earthquake activity, respectively. Subsequent weathering in central Washington's dry environment in the last 12,000 years has had minimal impact so that the flood-formed scarps and landslides appear to indicate a greater magnitude and frequency of historically recent tectonic activity than is warranted.

TABLE II.3-B-2

TIME AND GEOLOGIC EVENTS, PLIOCENE TO HOLOCENE EPOCHS, PASCO BASIN

EPOCH	AGE YRS BP	GEOLOGIC UNITS	GEOLOGIC AND RELATED EVENTS	CLIMATIC TRENDS
HOLOCENE	MODERN	LANDSLIDES	IRRIGATION-INDUCED LANDSLIDING	COOLER, MOISTER
		ASH DEPOSITS	ERUPTION OF MT. ST. HELENS	
	4,000	PALOUSE SOILS AND DUNES	DEFLATION OF COLD CREEK VALLEY, DUNE CREATION. MINIMAL MASS WASTING	
			COLUMBIA RIVER AT LOW FLOW RATE	ALTITHERMAL PERIOD
	6,600	MAZAMA ASH BED	ERUPTION OF MT. MAZAMA	
	8,000	EOLIAN SEDIMENTS	EXTINCTION OF MANY LARGE MAMMALS EARLY MAN KNOWN IN BASIN	
	10,000	TOUCHET BEDS LANDSLIDES	FLOODS TO AT LEAST 850 FEET ALTITUDE EXTENSIVE LANDSLIDING	
		GLACIER PEAK ASH BED	ERUPTION OF GLACIER PEAK EARLY MAN KNOWN AT MARMES ROCKSHELTER	PLUVIAL CLIMATE BECOMING WARMER AND DRIER
	12,000			
PLEISTOCENE		FLOOD DEPOSITS	CONTINUED ANTICLINAL UPLIFT AND BASINING FLOODS. DOMINANTLY GRAZING ANIMALS IN REGION	
	18 - 20,000	TOUCHET BEDS AND PASCO GRAVELS	CATASTROPHIC FLOODS FROM GLACIAL LAKE MISSOULA, POSSIBLY TO 1250 FEET ALTITUDE. EXTENSIVE EROSION, LANDSLIDING, SEDIMENT DEPOSITION	
		FLOOD DEPOSITS	FLOODS FROM GLACIAL LAKE MISSOULA AND LAKES TO THE WEST	ONSET OF THE ICE AGE WITH COOL CLIMATE AND AT LEAST LOCALLY INCREASED MOISTURE. REVERSALS IN INTER-GLACIAL PERIODS
	50,000	EARLY FLOOD DEPOSITS	GLACIAL LAKE MISSOULA FLOODS	
		FANGLOMERATES	PLANING OF THE RINGOLD FORMATION	
	1-2 MILLION			
PLIOCENE		EARLY PALOUSE SOILS	CONTINUED ANTICLINAL UPLIFT AND BASINING	
		RINGOLD FORMATION AND ASSOCIATED FANGLOMERATES	DOMINANTLY BROWSING ANIMALS IN THE REGION	
	8 MILLION	THE YOUNGEST BASALT FLOWS (POMONA, ELEPHANT MOUNTAIN AND WARD GAP)	TERMINATION OF THE BASALT FLOODS BEGINNING OF ANTICLINAL UPLIFT AND INCREASING VOLCANIC ACTIVITY IN THE CASCADE RANGE	DRYING AND COOLING

II.3-B.10 Volcanic Ash Deposits

Three and possibly four vitric tuff (volcanic ash) beds are known in the Pasco Basin where they occur in late Pleistocene and Holocene deposits and have at least tentatively been identified as to source.[16]

The oldest ash, a bifurcated bed with layers about a half-inch thick,[16] is associated with the last glacial Lake Missoula flood deposit. Traditionally considered to have been erupted from Glacier Peak in the north Cascades about 12,000 years ago, the lower bed of the two, as evidence now suggests, may have been from an eruption of Mt. St. Helens, nearly simultaneously with that of Glacier Peak. The ash beds are significant in that they lie within the uppermost part of the flood deposits to an altitude of 850 to 900 feet and above that in eolian sediments. The beds thus identify the deposits and height of the latest flood.

The most certainly identified ash bed in the Pasco Basin is that emanating from Mt. Mazama (Crater Lake, Oregon) about 6600 years ago. Normally about 6 inches thick, it lies within stream-deposited sands below an altitude of about 450 feet, and within eolian sediments above that altitude. It marks the course of the Columbia River 6000 to 7000 years ago.[28]

Mt. Mazama erupted in the midst of the Altithermal interval which was characterized by a warm, dry climate and low flow of the Columbia River. The ash bed identified geologic formations created in that period, including sand dunes.

The youngest ash bed currently is known only at Rattlesnake Springs. It is believed to correlate with an eruption of Mount St. Helens about 3200 years B.P. (Before Present).

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APPENDIX II.3-B, Part 2

Geological Studies of the Hanford Site

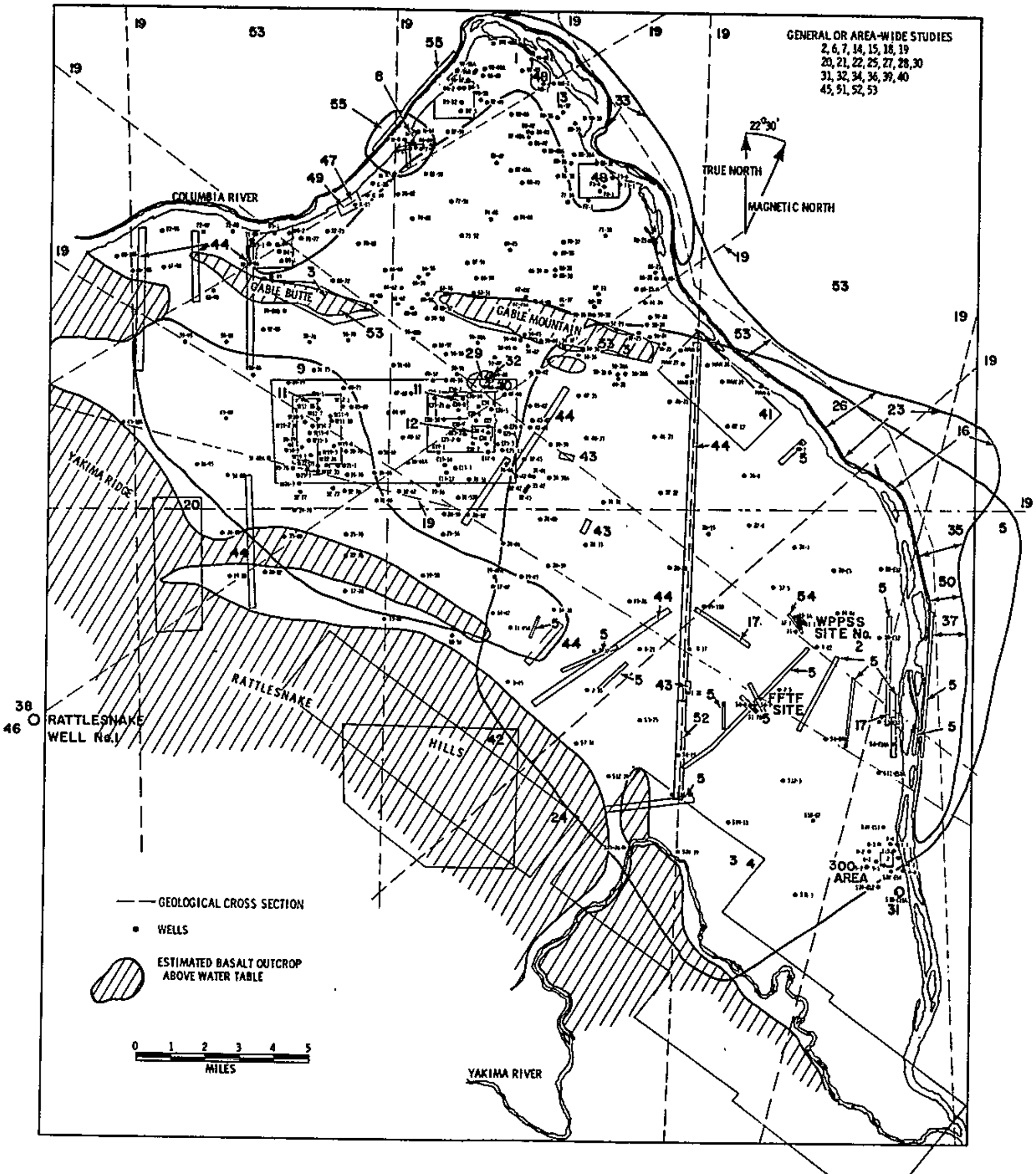

FIGURE II.3-B-5 OUTLINE MAP OF HANFORD RESERVATION AND PERIPHERAL SITES SHOWING THE SITES AND AREAS STUDIED AND AVAILABLE REPORTS ISSUED

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APPENDIX II.3-C

SEISMOLOGY

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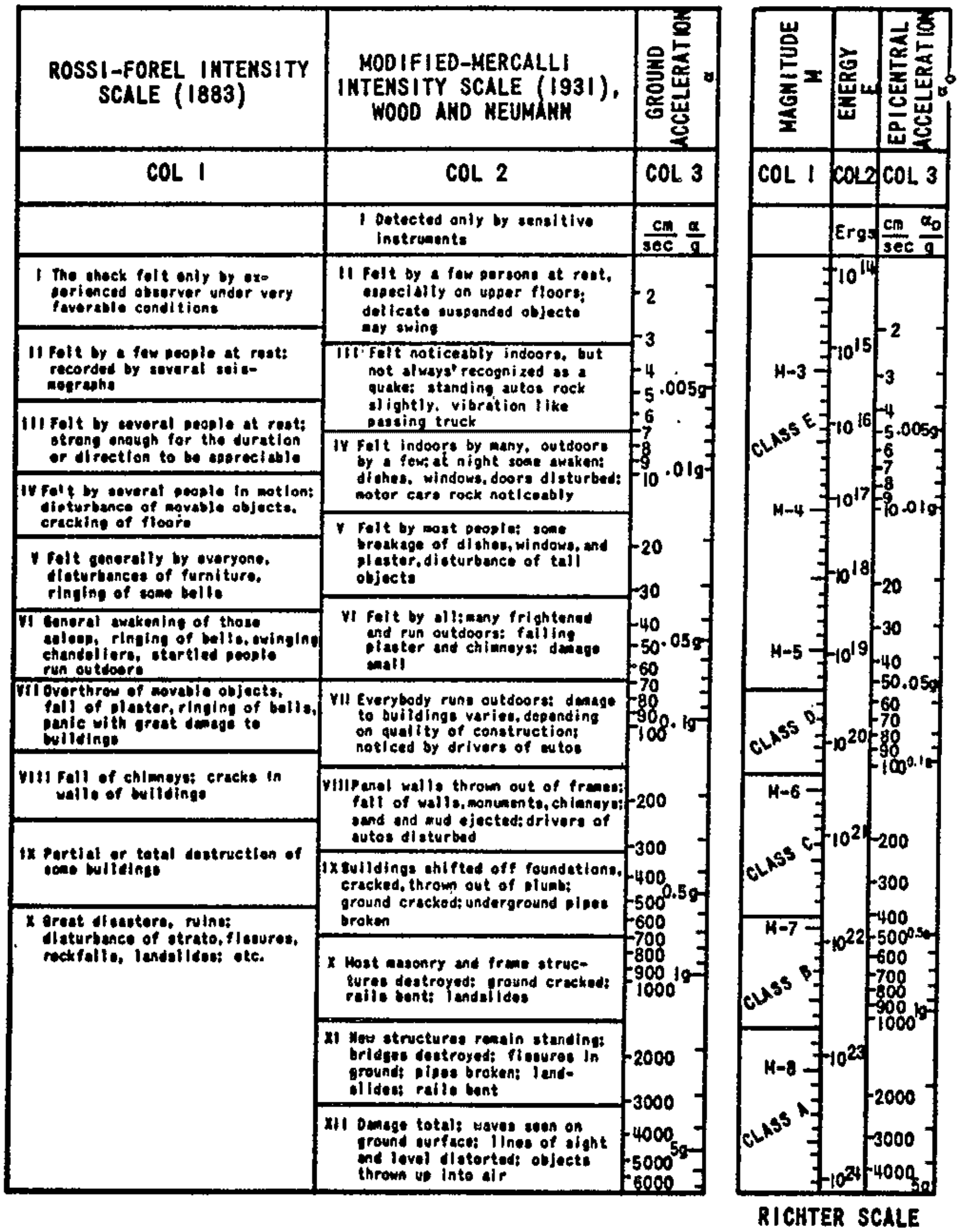
II.3-C SEISMOLOGY [X.25]

II.3-C.1 General

Eastern Washington is in a region of low to moderate seismicity that lies between the western Washington and western Montana zones of considerably greater seismicity.[1,2] On the basis of the damage that has occurred since 1840, the U.S. Coast and Geodetic Survey (ESSA) designated eastern Washington as Zone 2 seismic probability, implying the potential for moderate damage from earthquakes. Periodic revisions since 1948, the date of the first issuance of the risk map, and up to 1969, resulted in no changes in the potential for eastern Washington although other parts of the country were upgraded in the damage potential (Table II.3-C-1). Currently western Washington and western Montana are in Zone 3 category, implying the risk of considerable damage. The categories are incorporated in the Uniform Building Code.

TABLE II.3-C-1

APPROXIMATE RELATION CONNECTING EARTHQUAKE INTENSITY WITH ACCELERATION



The seismic risk maps are based upon the worst damage that has been experienced, mostly on poorly consolidated and saturated sediments that are the most responsive to earthquakes. Hence a pessimistic damage potential is indicated for sites utilizing less earthquake-responsive ground. In compensation, the maps consider only about 100 years of historical record, during which a low density of population may have resulted in no record of some minor quakes and certainly no damage. The true earthquake potential then may be somewhat higher than suggested by the Seismic Risk Map (Figure II.3-C-1). The upgrading in potential seismic damage in part may reflect increased population density and increased use of seismically responsive ground, and in some sites an actual increase with time in earthquake frequency and magnitude. Other methods of assessment clearly are required.

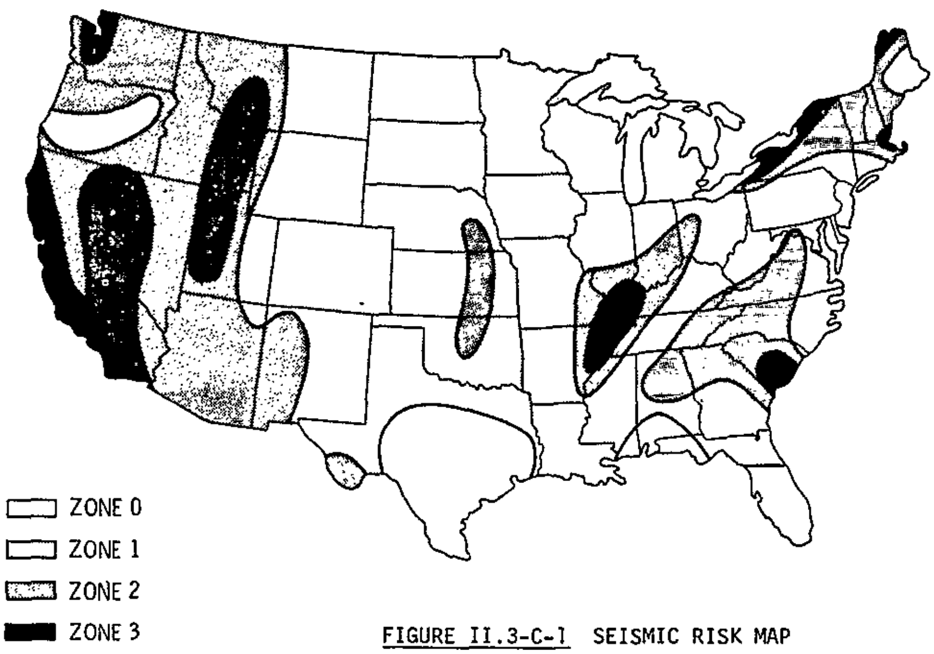


FIGURE II.3-C-1 SEISMIC RISK MAP

Movement on surface faults often is associated with earthquakes. However, many earthquakes occur without surface faulting and some faults move (creep) without significant earthquake activity. The presence of major faults or sharp folds subject to faulting are validly considered as evidence of possible past earthquake activity, possible future activity and possible epicenters.

The Pasco Basin is a broad, shallow topographic and structural depression evidently formed by long-term subsidence during which the vast volume of basaltic lava flows were emitted, probably from about 60 million years to 8 million years ago. Presumably the subsidence was slow and essentially continuous at an average rate of about 1 foot per 5000 years.[3] Various lines of evidence suggest appreciable variations from that rate, as can be expected.

Late in the stage of basalt flow emission, about 15 million years ago, anticlinal uplift began. The anticlines superficially resemble the fault-block structures of the seismically more active Basin and Range country of Southeastern Oregon, eastern California, Nevada and western Utah. Indeed at one time (early in the 1900's), the anticlines in eastern Washington were considered equivalent to the more southerly fault block structures and large faults were assumed present.[4]

A seismic comparability thus seemed warranted and was applied by some parties. However, the Zone 3 designation for the Basin and Range region and the Zone 2 designation for eastern Washington, on the basis of more than 100 years of record, imply significantly different environments. This, together with geologic information earlier discussed, is more realistic than assuming that the magnitude of earthquakes in eastern Washington will be equal to those in the Basin and Range country but with lower frequency. Separate and distinct appraisals of the potential are needed.

Both regions, as in fact all the western United States, developed largely in response to global-wide forces associated with plate tectonics (continental drift). This specifically involves the relative motion of the Pacific and North American plates, the precise effects of which are still largely obscure though undeniably present.

Progressively northward from San Francisco, the oceanic structures reflect the increasing dominance of the generally east-west trending transform faults associated with sea-floor spreading and global tectonics. The change is similar to the change in trend from the north-south features of California and Nevada through the transition zone of the Blue Mountains and the Snake River Plains to the east-west and northwest-southeast-trending structures of eastern Washington.

The Basin and Range Province formed from uplift in Mesozoic and Cenozoic time of the Cordilleran geosynclinal deposits during the Nevadan and Laramide Revolutions. East-west tensional forces in late Cenozoic time (the Cascadian-Alpine Revolution) caused a breakup of the early Rocky Mountain arch and the development of normal, high-angle faults. Accompanying this was the rotation of fault blocks about horizontal axes parallel to the faults. Strike-slip faults also were prominent. Igneous activity then occurred.[5]

The Columbia Basin formed by subsidence in Cenozoic time, accompanying and probably directly related to the emission of flood basalts from beneath the region. In late Cenozoic time (within the last 15 million years), the anticlinal ridges began to rise. Evidence suggests a north to south progression of uplift, a greater rate to the north, or both.

If the eastern Washington structures are analogous to the Basin and Range structures, they should show comparable effects of compression and tension. The Washington anticlines tend to be asymmetrical with the steep face to the north, containing some thrust faults commonly dipping south. This implies north-south compression. The abundance of high-angle reverse faults and reversal of asymmetry, however, suggest a strong component of vertical uplift. The Horse Heaven Hills, a tilted and uplifted plateau, is one classic example.

Faulting was, and still is, the dominant means of stratigraphic offset in the Basin and Range country throughout its development. The faulting in eastern Washington appears to be an early response, followed by folding, once the belts of deformation were established. Possibly compression in part is related to subsidence of the Basin, in which the uppermost flows in a probably 12,000 feet sequence would be under compression and the lowermost flows in that section would be under tension.

Subsequently, the major deformation was uplift and folding with little evidence of major compressional or tensional forces and little evidence of recent fault offset. This contrasts with the Basin and Range Province. The major episode of faulting tends to be in early Ringold Formation time (the Pliocene epoch).[6]

Deformation certainly can be continuing since energy release occurs as stress accumulates. Commonly, as noted by many workers, the stress is released by minor slippage on the many joints in the basalts and on often clay-rich interbeds between basalt flows. Distinct faults commonly are limited in lateral extent, possibly in depth, and in offset because they pass into bedding plane shear zones and splay out into joints.

A wide distribution of centers of minor energy release (epicenters) can be expected. This is the situation to date, rather than that the recorded micro-earthquakes cluster along linear zones coincident with the anticlinal ridges and the mapped and hypothesized faults.

Sparse earthquake data and a yet-inadequate understanding of the geologic features of the region preclude a finite tectonic model of eastern Washington. Various models can be applied to infer a comparability of seismicity. However, as with the Basin and Range analogy, differences in the geology are likely to be gross and evident enough that the validity of the comparison suffers.

A model has been proposed[7] that appears to explain the orientation of the gross tectonic features of the North American Cordillera (the main mountain region of the continent). Although simplistic and idealized, it offers a potential for a better understanding of the tectonic features one to another. Once the nature of the features is better understood through regional studies, their relationships to each other can better be assessed through the Wise or updated and modified models for a more meaningful seismicity determination.

II.3-C.2 The Olympic-Wallowa Lineament

An Olympic-Wallowa (topographic) lineament[8] has been cited as a possible major crustal rupture. Faults definitely are present at several locations along its strike, and the feature must represent, at least in some segments, an underlying or basement rock feature.

However, the Olympic-Wallowa lineament is not a sharply defined or continuous structure. As part of a broad zone not generally recognized, it appears related to a statewide grain or pattern. Along the west edge of the Hanford Reservation, the anticlines and synclines change their trends from east and west to northwest-southeast. The change occurs along a generally north-south line marking an increase in the eastward rate of plunge of the structures. The trend change occurs in the Horse Heaven Hills, the Rattlesnake Hills, the subsurface continuation of the Yakima Ridge anticlines, and in the Gable Butte and Gable Mountain structures, particularly in their subsurface extensions.

Possibly, in the process of maximum subsidence of the Pasco Basin between the Hog Ranch and Jackass Mountain monoclinal flexures, the effect of pre-existing structures was felt. Throughout the Cascade Range drainage patterns reflect a northwest-southeast trend that is identified as the remnants of an Oligocene-age Calkins Range. Evidence of that range also is present in the Willapa Hills of southwestern Washington, the Olympic Peninsula, and the San Juan Islands.

The origin of the Calkins Range and/or the northwest-southeast trending segments of eastern Washington's anticlines is certainly obscure and can only be postulated. Evidence indicates a clear-cut superposition of several periods of deformation and consequent structures one upon another which compounds the problems of an evaluation of the seismic hazard.

Geologic evidence suggests that the Horse Heaven Hills may be a more important geologic and tectonic feature, hence potentially a more significant earthquake-generator, than the Olympic-Wallowa topographic lineament and its hypothesized structure of uncertain significance. The Horse Heaven Hills:

- are structured continuously from the Blue Mountains to the Cascade Range and with appreciable relief throughout its course. (The Olympic-Wallowa Lineament is discontinuous, interrupted by other structures, and locally of no relief.)
- are structured with continuously large total stratigraphic offset and inferred local dip-slip fault offset of 300 feet. Fault offset on the lineament is more than about 200 feet.[6]
- have several sites of tentatively recent fault offset. One is six to seven miles west of Milton-Freewater; one is near Warm Springs six to eight miles east of the Columbia River. A third site is about four miles west of Prosser where clastic dikes, filled with Touchet Beds sediments, have cut and offset Ellensburg Formation Beds about 20 feet. The age of the fault offset is probably 12,000 years. The offset in the first two instances could be on either the lineament or the Horse Heaven Hills structures.
- are the locale of the Milton-Freewater earthquake of 1936 and the Umatilla quake of 1893. Seven other earthquakes were noted and recorded by the Blue Mountain Observatory, and epicenters were identified in the northern reaches of the Blue Mountains or in the Horse Heaven Hills.[4] The Blue Mountain structures cross the lineament and have not been affected by it;[9] the Horse Heaven Hills show evidence of recent uplift, away from the lineament. Hence both ranges show evidence of tectonic activity more recent than structures on the Olympic-Wallowa Lineament.

Shortened, more realistic versions of the Olympic-Wallowa zone were proposed along which faulting was demonstrated and which conceivably could be the epicenters of earthquakes.[1] The Rattlesnake-Wallula topographic lineament is one example.[6] Faulting locally terminates at the Yakima River water gap (the southeast end of the Rattlesnake Hills) without clear-cut evidence of its continuation farther northwestward. On the assumption that a significant fault or structure capable of faulting exists there and can generate earthquakes, the site is considered to be the possible epicenter for the maximum credible earthquake in the Pasco Basin.

Thus the Rattlesnake-Wallula lineament can be explained as an offshoot structure of the Horse Heaven Hills rather than as the major or dominant feature. The potential of an earthquake at this site is appreciably remote.

II.3-C.3 <u>The Saddle Mountains</u>

The second likeliest epicentral location for earthquakes is the Saddle Mountains, bordering the Pasco Basin on the north, more remote from most Hanford facilities than the Rattlesnake-Wallula lineament, except for the northernmost part of the Reservation. This is especially true if the Rattlesnake Hills, the projection of that lineament, are considered capable of surface faulting. Hence the Saddle Mountains are of lesser concern to the whole of the Reservation.

The mapped and hypothesized faults along the north face of the Saddle Mountains die out eastward with the diminution of the Saddle Mountains and have not been hypothesized east of about Corfu. The faults have been traced west of the Columbia River about 15 miles.[10]

Studies in 1965[1] emphasized the significance of the Saddle Mountains faults and considered that the Corfu quake of 1918 occurred along that fault, caused numerous landslides and that a fault scarp had formed in recent times. However, the U.S. Geological Survey demonstrated that the site reputed to show offset was an area of block glide, resulting probably from the effect of the glacial Lake Missoula floods 12,000 or more years ago.[6] Moreover, the larger landslides in most instances appear to have been caused by the same floods,[10] not the Corfu quake, and recent surveys have suggested that such slides resulting from that quake were minimal. The Survey's conclusion was that no movement on the fault has occurred in at least 12,000 years. This was determined by ^{14}C dating of organic matter in eolian silts that lay undisturbed across the fault trace.

Much of the concern for the Saddle Mountains faults relates to the Corfu earthquake of November 1, 1918. Based on the location of the sole reporter of the quake, it occurred at or even east of the east end of the surface trace of the faults. The epicentral location is uncertain because only one person initially reported it and the quake was uninstrumented. Subsequently the quake was, for uncertain reasons, translocated to the northernmost part of the Hanford Reservation. Because earthquakes commonly occur along faults, a major eastwest fault was hypothesized through the translocated epicenter in the Wahluke Syncline. As indicated earlier, all major faults in the region appear associated with anticlinal folds and have their greatest offset in the areas of maximum total relief. Hence, the epicenter in a major syncline appears unrealistic. Because of the uncertain location, similar to the uncertain extent of faulting along the Rattlesnake-Wallula lineament, the epicenter was conservatively assumed to have been beneath the Hanford Reservation.

Recent studies[12] confirmed the presence of faults in the Saddle Mountains, offset comparable to that determined by the Geological Survey, and an absence of evidence indicating recent movement.

II.3-C.4 Other Structures

Study of the Manastash Ridge--Hanson Creek anticline, between the Saddle Mountains and Umtanum Ridge and west of the Pasco Basin--disclosed a typical situation there.[12] The anticline is asymmetrical with the steep dip to the north, the anticlinal axis is sinuous, and one or more high angle reverse faults border the north side of the anticline. They emphasize the spatial relationship between the close folding and faulting. Stratigraphic offset on the faults is estimated at 500 feet in the east end of the structure and about 800 feet on the west end of the structure.

The anticline can be projected to the east side of the Columbia River where evidence tentatively indicates the fault is also present. The sinuosity of the anticlinal axis and the fault make projection farther east difficult. The structure evidently dies out eastward, similar to the structures to the north and south, and cannot be recognized within 20 miles of the WPPSS steam generating plant. This emphasizes the probable absence of a significant fault in the Wahluke Syncline along which the translocated Corfu quake could have originated.

Additional work in Umtanum Ridge confirmed previous conclusions. The Ridge is an asymmetrical anticline with the steep face to the north; locally the north limb is overturned. The anticlinal axis is sinuous. A high-angle reverse fault borders the north face. Erosion by the glacial Lake Missoula floods removed much of the north limb of the structure so that the fault is generally exposed and traceable only for a short distance to the east from the Priest Rapids Dam site. The fault can be projected to within about 12 miles of the WPPSS steam generating plant where it evidently dies out and is superseded by the sequence of generally northwest-southeast-trending en echelon anticlines and synclines of the Gable Butte-Gable Mountain complex. A north-south tending thrust fault(s) is present in Gable Mountain but has not moved in more than 40,000 years.[6] Normal or high-angle reverse faults may trend west-northwest along the north face of Gable Mountain and Gable Butte and the dissected anticline two miles west of 100-B Area. If so, they must be less than a few miles long because of the position and trend of the anticlines relative to the total uplift.

Stratigraphic offset on the Umtanum Fault is uncertain but is estimated at 500 to 1300 feet, with the south side upraised. The fault is a high-angle reverse fault. Since the Pasco Gravels which overlie the fault show no signs of offset, the last movement, as in the Saddle Mountains, was probably at least 12,000 years ago and may be more than 40,000 years ago, as dated at Gable Mountain, the eastward continuation of Umtanum Ridge. The main period of movement on the fault probably was during Ringold Formation time and the initial uplift of the anticlinal ridges. If the Umtanum Ridge structure was the first in the Basin to rise, the age of the initial period of faulting could exceed 10 million years.

The faults in the northern part of the Pasco Basin are considered inactive on the basis of lack of topographic expression, lack of evidence of movement within the last 35,000 years or multiple movement in the last 500,000 years, and no relationship to a known active fault. Other than the Corfu quake, which is of uncertain epicentral location, magnitude and intensity, no macro earthquakes associated with known faults have occurred.

The faults bordering the Horse Heaven Hills, including those that lie along the various versions of the Olympic-Wallowa Lineament, apparently are the sites for potentially active surface faults in the Pasco Basin. Logically then, they are the sites for the maximum credible earthquake in the Pasco Basin.

II.3-C.5 The Effects of Earthquakes

The most significant single consideration in earthquake engineering is the nature of the foundation materials, as alluded to in the discussion on the seismic risk map. This is important from the standpoint of 1) rupture of the ground beneath a facility by propagation of fault movement, 2) vibration of the ground, and 3) differential compaction, liquefaction and landsliding.

Ground rupture occurs directly above a fault when movement along that fault propagates to the ground surface, in some instances at short distances from the fault plane. These risks can be prevented by avoiding faults by appropriate distances. Because all significant and especially active faults are associated at least spatially with the anticlinal ridges, avoidance of the anticlines is desirable and usually sufficient protection.

Ground vibration is the dominant concern in earthquake engineering because facilities many tens of miles from the epicenter may be damaged or destroyed and because to precisely determine the expected ground motion is difficult. Local geological factors can spread the range of observed intensities over at least four grades, each grade representing ground motions that have double the amplitudes found in the next lowest grade.[13] This means an eightfold range in amplitudes over a four-grade range of MM intensity. Local confirmation of this is suggested by several events as noted. Other factors are not yet adequately understood and may contribute to the differences:

- Prosser has one of the higher seismic foundation factors in the area, as indicated by the Milton-Freewater earthquake of 1936,[13] the Olympia earthquake of 1949, and the Horse Heaven Hills quake of July 26, 1965. In those instances, Prosser responded more than Hanford or other adjoining areas.

- Records of reactor area and building response have shown different responses of the same area and buildings to roughly comparable quakes, and different responses of different areas and buildings within those areas to the same quake.

The precise response of the ground to the full spectrum of waves is a complex function that can best be understood only by the repeated observation of events. In some instances, especially with the short period waves, alluvium may damp out the ground motion. Thus, a prevailing period of vibration of 0.2 sec for short period waves in Hanford sediments poses little problem. However, longer period waves may be amplified, especially if the wave period coincides with as yet inadequately identified natural long periods of vibration of the geologic formations. The possibility of selective frequency effects thus requires that the dynamic properties of the structures be considered when assessing the effect of local geology.[15]

II.3-C.5.1 Differential Compaction

Differential compaction is common in unconsolidated alluvium and was a major cause of damage during the Prince William Sound (Anchorage) earthquake of 1964. The sediments at Hanford have a high degree of natural compaction. The Ringold Formation sediments at one time filled the Basin to an altitude of about 1000 feet (the crest of the White Bluffs), but have been eroded in part from the Hanford Reservation. They have been irregularly covered subsequently by later sediments, the Pasco Gravels. Hence, at one time 200 to 600 feet more sediments existed as a static load than now are present over the topmost Ringold Formation beds, a factor in their compaction. The beds, too, are low in permeability, owing to their age, the resulting cementation and opportunity for compaction subsequent to deposition. Those factors and the relatively high seismic (P) wave velocity of about 6000 to 12,000 ft/sec confirm the compaction.

The Pasco Gravels and their fine-grained equivalent, the Touchet Beds, were laid down by the glacial Lake Missoula floods. The gravels that underlie all but the basin margins commonly are open-work or semiopen-work gravels with high permeabilities. Seismic (P) wave velocities are consistently low, about 2000 ft/sec. However, their load-bearing capacity without undue settlement is high, generally in excess of 6000 lb/ft^2 even for materials directly at the ground surface. Commonly 10,000 to 12,000 lb/ft^2 are measured.[12] That high load-bearing capacity of the flood deposits is attributed to the point-to-point contact between cobbles and pebbles and the subsequent interstitial filling by finer-grained sediments as the floodwater velocities slackened. Thus loads are supported on columns of cobbles and pebbles.

The Ringold Formation generally is saturated and the Pasco Gravels commonly are dry except locally where they are normally saturated for only a few tens of feet of depth at the base of the gravel. Consequently the opportunity for reworking and compaction is minimal. Even where large quantities of water pass to ground and where vibrational and differential loading occur on undisturbed ground, settlement has been negligible. Differential compaction on undisturbed ground is of minimal concern.

II.3-C.5.2 Liquefaction

Due to the prevailing dry environment and as long as the potentially liquefiable sediments remain confined, the likelihood of liquefaction of Hanford sediments is very remote.

The sediments lying at and near the ground surface (the Pasco Gravels and uppermost Ringold Formation beds) to depths of 110 feet have been compared to the range of gradation of liquefiable soils.[12] If saturated and if a face were free toward which they could move, a few samples found were sufficiently fine grained and clean to be potentially liquefiable. Most materials had a high relative density (were compact), a coarse grain size and good size gradations. The silts and clays that lie below the groundwater table were of high plasticity but "are also insensitive and exhibit high shear strength in excess of 3 to 5 tons per square foot."[12] This is, in part, the result of deposition in a calcium-rich environment, some resulting cementation, compaction under high load, and maintenance of the calcium-rich environment for millions of years. The deposited clays were not changed to forms liable to liquefaction in a chemically changed environment.

Some sands in the Ringold Formation are clean, uncemented and well sorted. Upon penetration by wells (a face toward which to flow), the sand rises in the wells. This is not liquefaction in the sense of rearrangement of particles to occupy a lesser volume; it is controlled by appropriate confinement of the sand.

II.3-C.5.3 Landslides

Many landslides are present in the region and have been attributed to earthquake activity, as earlier noted. However, they are but permissive evidence of earthquakes and more commonly result from excess water in the ground. A classic case is that of the slides along the north face of the Saddle Mountains, attributed by some persons to earthquakes, especially the Corfu quake. In view of the findings in recent years, the indications are that most of the features are related to the glacial Lake Missoula flood of about 12,000 years ago, not historically recent quakes. Water primarily decreases the shear strength of the clay-rich beds, which together with the pore pressure gradient at the draining face and the weight of the water often permit minor earthquakes to trigger the slides. In the case of floods, the erosive action on the toes of slopes also contributes.

Existing natural slopes on the Reservation have been determined to be stable; only those slopes on the enclosing anticlinal ridges, Gable Mountain, Wahluke Slope and the White Bluffs are steep enough for concern. Of these, the White Bluffs pose the greatest concern because of 1) the clay-rich nature of some beds above river level and within the Ringold Formation, 2) discharge of large quantities of irrigation water to ground atop the bluffs, 3) gentle dips of the Ringold beds toward the Columbia River, and 4) the eastward shifting of the Columbia River and its undercutting of the bluffs. Slides of a million or more cubic yards have occurred within the last about 12,000 years; consequently, more are expected. Not likely to be impounded, the river would more likely be diverted to a more westward channel in the slides areas.

II.3-C.6 Maximum Anticipated Earthquake

The Corfu earthquake (Modified Mercalli intensity IV to V) probably caused the maximum historical ground motion on the Hanford Reservation. The Milton-Freewater earthquake of 1936 and the Umatilla earthquake of 1893 were of higher intensity at their epicenters but sufficiently remote to result in less ground motion at Hanford. If the Corfu earthquake is assumed to be a full

MM-V and with its epicenter on the Hanford Reservation,[1] rather than on the Saddle Mountains, the ground acceleration would have been three percent of gravity (3% g). This is roughly equivalent to a Richter magnitude 5 earthquake (Table II.3-C-1).

Faults or structures capable of surface faulting are assumed present along the Olympic-Wallowa lineament and its shorter, more realistic versions. An earthquake comparable to the Milton-Freewater quake could occur at the northwest end of the zone of identified faulting, at the southeast end of the Rattlesnake Hills. However, the Rattlesnake-Wallula zone of faulting ends at the Yakima River so that neither surface-faulting nor recent offset is present. Migration of activity and offset along a fault can and does occur. The fact that it has not yet occurred in spite of the more than 10 million years of tectonic deformation suggests an extremely low probability that it would ever occur.

However, if such an improbable MM-VII quake were to occur along that zone at its nearest approach to Hanford, the acceleration at the epicenter would be about 15% g. This is fully consistent with zone requirements of the Seismic Probability Map, for a building on firm alluvium and not near a great fault, as follows:

Zone 3	33% g	Zone 1	8% g
Zone 2	16% g	Zone 0	4% g

At a distance of 15 miles from the epicenter, the average distance to Hanford sites from the postulated epicenter, the acceleration would be reduced to 6%[17] to 13% g,[12] with a probable corresponding increase in the duration of the quake.[13]

A summary of the conclusions of various authorities in seismology as to the maximum anticipated earthquake is as follows:

Frank Neumann[13]	MM-VII in total basin	N. H. Rasmussen[2]	Magnitude 5.8
Capt. R. A. Earle[11] (USC&GS)	MM-IV maximum historically recorded in the Pasco Basin	R. H. Jahns[16]	Magnitude 5.5
		G. W. Housner	Magnitude 5.5
Holmes & Narver[15]	MM-VIII (25% g) maximum credible earthquake	John A. Blume Assoc.[17]	Magnitude 6.8, MM-VIII maximum credible earthquake (conservative)

All authorities have concurred in the 25% g acceleration level for the Safe Shutdown Earthquake (formerly the Design Basis Earthquake). This is consistent with the vibratory acceleration associated with an intensity MM-VIII quake, larger than any known east of the Cascades in Oregon or Washington. An MM-VIII quake is consistent with the full-fledged Zone 3 of the Seismic Probability Map, not the Zone 2 recognized since 1949 by that map.

In March 1969, the U.S. Geological Survey established an array of six high sensitivity seismometers on and around the Hanford Reservation. The purpose was to attempt to determine the macroseismic characteristics of the region through recording of the microearthquakes. By October 1971, 24 stations were operating. Of the more than 1000 microearthquakes recorded very few have occurred south of the Hanford Reservation, especially along the Olympic-Wallowa lineament or its abbreviated versions. This is "moderate by comparison with the microearthquake activity of seismically active regions of California and Nevada where similar monitoring studies have been made."[6]

By far, the bulk of the microearthquakes have occurred in the eastern to northern part of the Pasco Basin, from Wooded Island to the east end of the Wahluke Slope. Few quakes in that group are sufficiently close to mapped or postulated faults or sharp folds to be directly related to them. Some events further east appear related to blasting by contractors (to the Corps of Engineers) on railroad relocations for Snake River dams. Some others may have resulted from construction work (by Burlington-Northern, Inc.) on roadbeds across Wahluke Slope. Others may have occurred because of near-surface crustal loading by irrigation water. If the Pasco Basin is slowly deforming, then the addition of several hundred feet of water, as indicated by rising water tables,[18] could impose stresses above and beyond those naturally imposed. The abundance of microearthquakes in and near the Columbia Basin Irrigation Project suggests such a cause.

Large numbers of microearthquakes have occurred near the north-south trending Jackass Mountain monoclinal flexure where the basalt flows turn downward toward the Pasco Basin center. Folding could result in the release of many small amounts of energy along joints and bedding planes in an essentially random pattern.

Only one earthquake of the more than 1000 recorded has exceeded the Richter magnitude 4 quake necessary for good analysis. That quake occurred December 19, 1973. The epicenter lay two to three miles north of Corfu and the magnitude was between 4 and 4.25. The quake occurred north and east of the surface trace of the Saddle Mountains fault and not near any other postulated fault.

The second largest quake recorded by the U.S. Geological Survey was a magnitude 3.2 quake that occurred on October 25, 1971. Its epicenter was beneath the central part of Wahluke Slope, close to the north bank of the Columbia River, and within the Wahluke syncline. Its focal depth was 3 km. A fault plane solution indicates thrust faulting resulting from north-south compression, probably the result of regional deformation.

II.3-C.7 Summary and Conclusions

Eastern Washington lies in a region characterized by few earthquakes of damaging or potentially damaging intensity. No clear-cut relationships of epicenters to specific surface faults or structures capable of faulting are yet recognized. The suggested low rate of tectonic deformation for probably more than 10 million years does not indicate cause for concern. Much of the stress resulting from the continuing low rate of tectonic deformation appears to be dissipated from random epicenters along joints and bedding planes.

On the assumption that a very low probability MM-VII quake (magnitude 5.5) were to occur at the northwest end of the Rattlesnake-Wallula fault zone, ground acceleration of 13% g could be expected beneath most of the Reservation. A design basis of 25% g on the Hanford Reservation allows for an MM-VIII intensity quake (magnitude up to 6.8) for an earthquake epicentered at the same site. No such quake has ever been recorded in eastern Oregon or Washington.

The siting of nuclear facilities over the synclinal troughs provides the maximum distance from all hypothesized faults capable of earthquake generation. If, in addition, the Ringold Formation and Pasco Gravels are compact and undisturbed, the site will certainly pose few problems.

An appreciable-to-high degree of conservatism exists by acceptance of the MM-VIII, magnitude 6.8 quake, and the resulting 25% g acceleration for the Design Basis Earthquake.

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APPENDIX II.3-D

HYDROLOGY

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II.3-D HYDROLOGY [X.18, X.24, X.25]

II.3-D.1 Regional Hydrology

II.3-D.1.1 Topography and Drainage

As Figure II.3-D-1 (a map of the Columbia River Drainage Basin) shows, the Hanford Reservation lies along the Columbia River just north of (upstream from) the confluence with the Yakima River. The surface drainage ways in the Hanford Reservation are depicted in Figure II.3-D-2. Drainage in the northeastern two-thirds of the Reservation is to the Columbia River directly, while drainage of the soutwestern third is actually into the Yakima River Drainage Basin, a subdivision of the Columbia River Drainage Basin.

The Yakima River, a major tributary of the Columbia River, has an overall length of about 180 miles and a drainage basin of about 6,000 square miles. The river heads in the rugged eastern slopes of the Cascade Mountains and flows southeastward into the semiarid region of central Washington. It joins the Columbia River only a few miles north of the confluence with the Snake River. Altitudes in the Yakima Basin range from 8,200 feet at Goat Rocks to 320 feet at the mouth of the Yakima River. Glaciers are present along the western edge of the basin in areas where the land surface is about 7,000 feet. Streams in the Yakima River have the greatest incidence of flood in May and June when the snow melts more rapidly at higher altitudes.

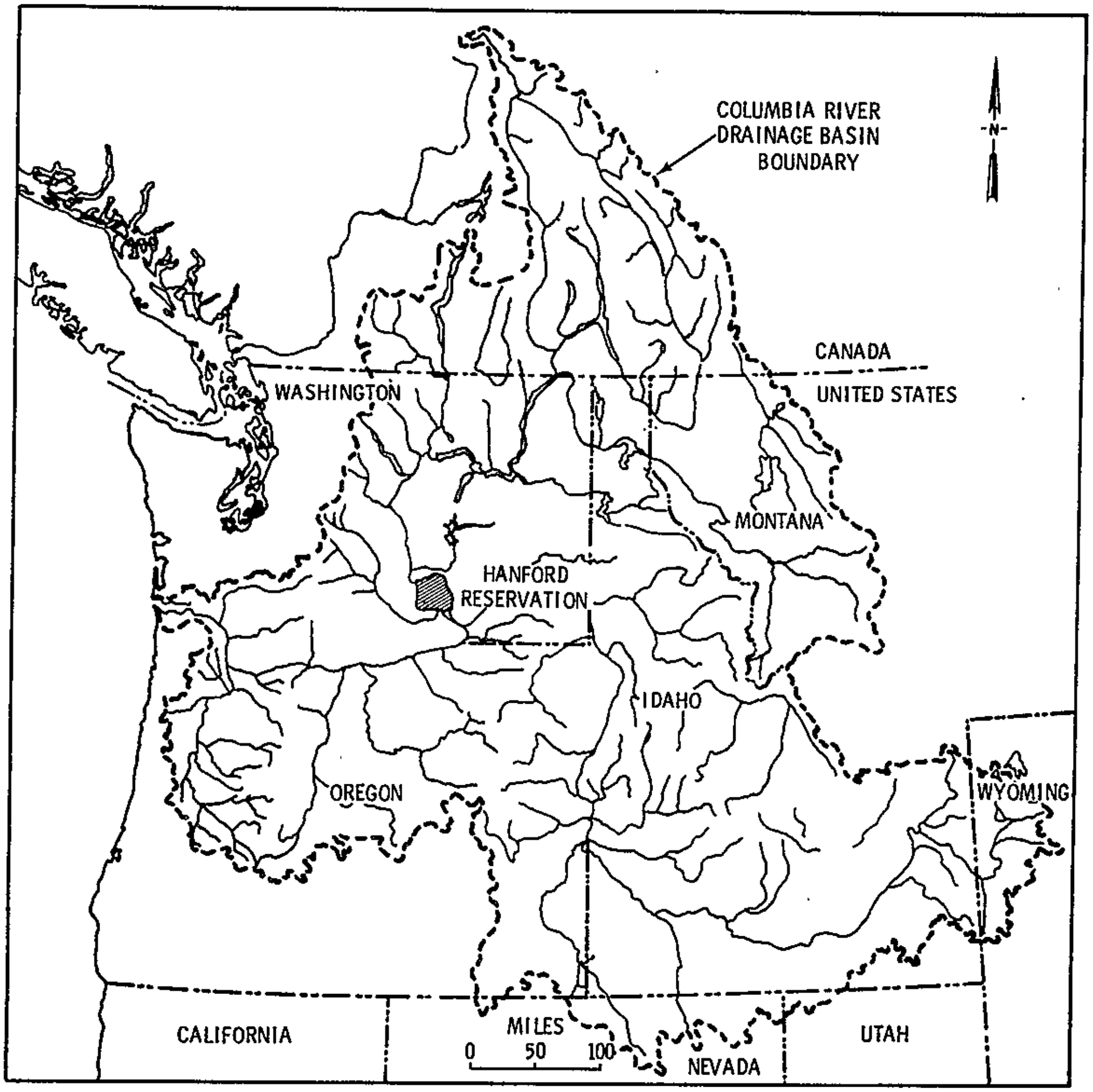


FIGURE II.3-D-1 THE COLUMBIA RIVER DRAINAGE BASIN

9 1 1 1 8 9 1 2 4 0

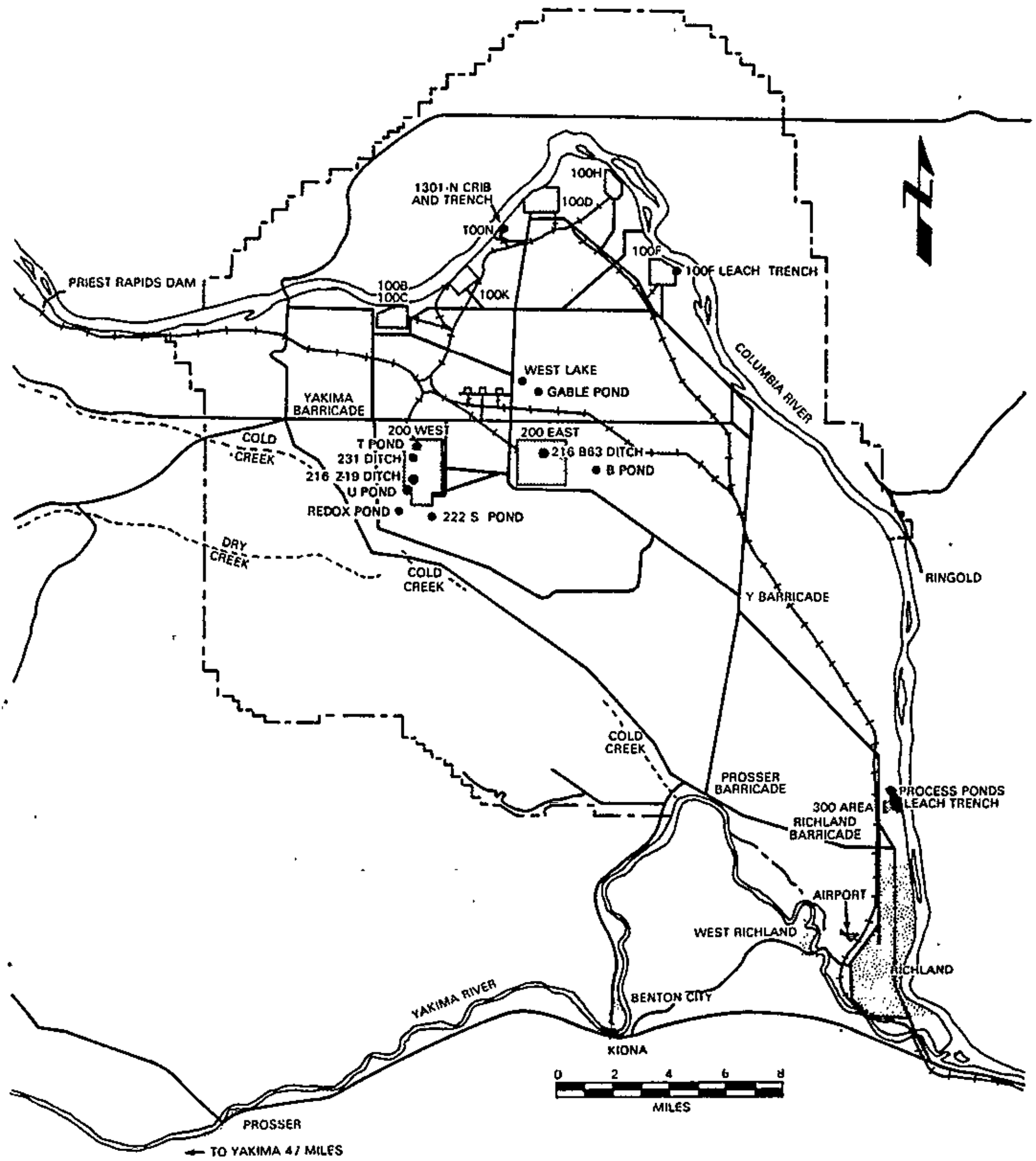


FIGURE II.3-D-2 SURFACE WATER AREAS ON HANFORD RESERVATION

II.3-D.1.2 Geologic Setting

Examination of the geologic map of Washington[1] reveals that the Columbia River Drainage Basin occupies two distinctly different geologic terranes. The western terrane encompasses the Cascade Mountains where relatively old sedimentary, volcanic, and intrusive rocks have been uplifted and dislocated by erosion into the rugged mountains. The eastern terrane derives from a thick sequence of basalt flows (the Columbia River Basalt Group) folded into numerous southeast to east trending anticlinal ridges and synclinal valleys. Clastic sedimentary rocks partly fill the synclinal valleys to depths exceeding 1,500 feet in some of the larger valleys. The Hanford Reservation lies almost entirely within the Pasco Basin, one of the larger synclinal valleys in the eastern terrane.

II.3-D.1.3 Flow Systems

Direct precipitation over the Hanford Reservation mostly evaporates leaving a minimal amount of water as land runoff and for infiltration. The Yakima and the Columbia Rivers are the only two permanent streams in the area. Cold and Dry Creeks carry water only during the spring season.

9 1 1 8 9 1 2 2 4 1

The natural groundwater flow system underlying the Hanford Reservation has been superimposed by three synthetic flow systems: 1) the 200 West Area, 2) the 200 East Area, and 3) Gable Mountain Pond. Approximately one-third of the liquid disposed at Hanford is received by the 200 West Area flow system which apparently (using piezometers[2]) underflows the 200 East Area flow system.

Figure II.3-D-3 is an isometric projection used in groundwater studies. The figure shows the Hanford groundwater table with exaggeration in the vertical dimension. Such a projection permits visual inspection of the changing groundwater gradients.

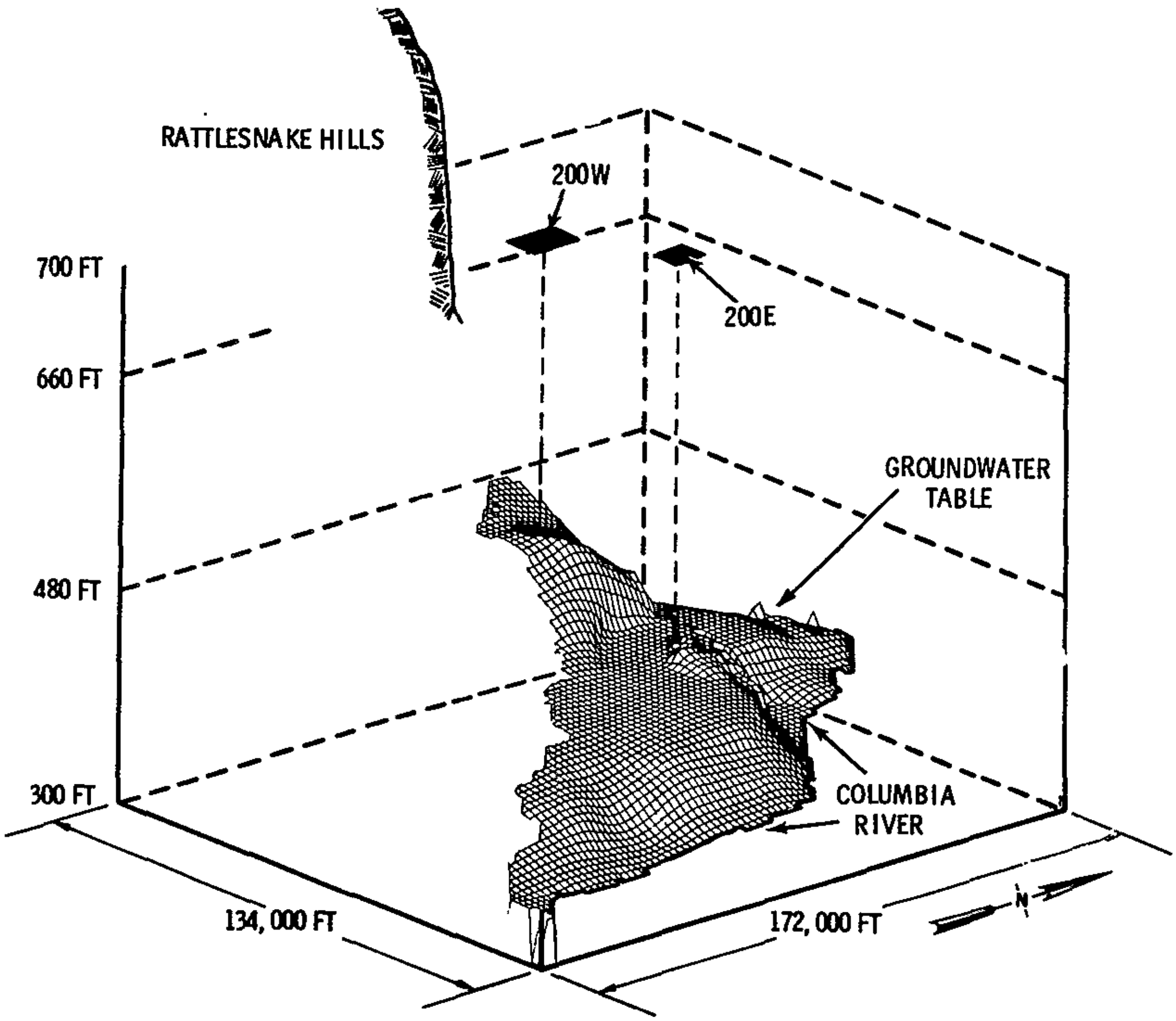


FIGURE II.3-D-3 ISOMETRIC PROJECTION OF THE GROUNDWATER TABLE UNDER THE HANFORD RESERVATION

II.3-D.2 Surface Waters

II.3-D.2.1 The Columbia River [X.18]

Hydraulic Characteristics

The river reach from Priest Rapids Dam (river mile 397) to the head of the reservoir behind McNary Dam (approximately river mile 351) is the last free-flowing reach of the Columbia River within the United States. The main channel is braided around the island reaches and submerged rock ledges and gravel bars causing repeated pooling and channeling. The riverbed material is mobile and dependent on river velocities; it is typically sand, gravel, and rocks up to 8 inches in diameter. Small fractions of silts and clays are associated with the sands in areas of low-velocity deposition, becoming more dominant approaching the upstream face of each river dam.[3]

The Columbia River in this reach has widely varying flows, not only from the annual flood flow, but also due to daily regulation by the power-producing Priest Rapids Dam just upstream. Flow rates during the late summer, fall, and winter may vary from a low of 36,000 cfs (cubic feet per second) to as much as 160,000 cfs each day. During the spring runoff, peak flow rates from 160,000 cfs to 650,000 cfs have been observed. A maximum discharge of 692,000 cfs was recorded on June 12, 1948 while the minimum discharge of 4,120 cfs was recorded on February 10, 1932. Continuous flow data in the vicinity of Hanford is available from the gauging station maintained just below Priest Rapids Dam. Data[4] from this station and its predecessor near Rock Island Dam show a 55-year average flow of 120,800 cfs but during low flow periods, daily flow rates may average around 80,000 cfs or less. The flow variation for 1972 is given in Figure II.3-D-4; the mean annual flow rate was 159,500 cfs.

River cross sections have been determined for a number of flow rates.[4] The river width normally varies between 400 and 600 yards, depending upon the flow rate and location. The depth at the deepest part of the measured cross sections varies from approximately 10 to 40 feet and averages about 25 feet. However, the hourly variations in releases from Priest Rapids Dam can cause elevation changes during the day of as much as 10 feet upstream of Coyote Rapids and 3 to 5 feet downstream as far as Hanford. River stage measurements as a function of flow rate have been made at numerous points along the river in conjunction with reactor design and operation.[5,6,7,8,9]

Velocity measurements in the river have been made at selected locations, usually in conjunction with temperature and radioactivity surveys, and have included both surface velocity and velocity as a function of depth. Surface and vertical velocity profiles have been drawn from these measurements.[5,7] The maximum velocities measured vary from less than 3 feet per second (fps) to over 11 fps, depending upon the river cross section and flow rate.

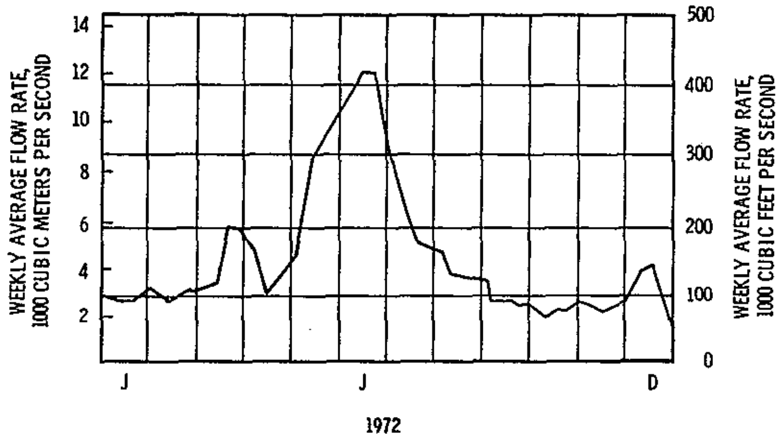


FIGURE II.3-D-4 FLOW VARIATION FOR 1972 - PRIEST RAPIDS DAM

Travel times in the river have been measured by a number of different methods. Radioactive tracers present in the reactor effluent and float methods were used in early work.[8,10,11] Later studies with dye injection have confirmed these early measurements. River flow rates, elevations, and travel times in the reservoir behind McNary Dam are strongly influenced by regulation of river flows at McNary Dam, as well as at Ice Harbor Dam on the Snake River.

(Additional references[12,13,14] on the hydraulic characteristics of the Columbia River are available.)

Temperatures

River temperatures have been measured at a number of locations both above and below the Hanford Reservation for many years with varying detail, methods, and instrumentation. The increase in dam construction and the interest in the effects of operation of the Hanford reactors gave rise to additional monitoring stations for measuring temperature along the river. Since the measurements were not always accurate enough to properly and consistently characterize downstream temperatures, starting in 1965 and lasting through 1970, special efforts were made to ensure that the measured temperatures accurately represented the temperatures of the fully mixed river.[12,13,15,16,17,18]

Tables II.3-D-1 and II.3-D-2 give the monthly average temperatures below Priest Rapids Dam and at Richland, respectively.

Analysis of the temperature trends recorded with the data shows that dam construction on the Columbia has delayed the annual peak temperature arrival dates in direct proportion to the increase in travel time due to the dam.[12,17,18,19] The free flowing stretch of river along the Hanford reach responds more rapidly to thermal modification from both weather and industrial inputs than impounded regions. Hence, in this stretch of river, summer warming and winter cooling occur more rapidly. Studies have indicated that about 65% of the heat input to the Hanford reach of the river is dissipated by the time it reaches the Washington-Oregon border.[18] The residual heat below McNary Dam from Hanford input for the 1965-1969 period was about equal to the effect the Snake River has on the Columbia River temperature. The mean temperature rise from natural heating along the Hanford stretch during the period of maximum natural heating in August and September is about 0.5 to 0.75°C.

Chemical

Chemical analyses are made annually on the Columbia River water at Priest Rapids Dam (routinely published[20]). The chemical analyses for water year October 1971 to September 1972 are given in Table II.3-D-3. The effect of reactor effluent on the chemical quality of the river water can

TABLE II.3-D-1

MONTHLY AVERAGE TEMPERATURE (°C) AT PRIEST RAPIDS DAM

Year	J	F	M	A	M	J	J	A	S	O	N	D
1961	5.4	4.7	4.7	7.4	10.4	13.7	17.3	18.9	17.8	14.9	10.4	6.6
1962	4.1	3.6	3.6	6.5	10.0	13.7	16.1	17.4	17.1	14.8	11.9	8.9
1963	5.3	3.8	4.6	6.5	10.4	14.0	16.6	18.4	18.3	16.3	11.9	7.7
1964	5.5	4.6	4.7	7.2	9.7	12.8	15.3	17.1	16.3	14.6	10.8	6.3
1965	4.4	3.3	4.1	6.6	10.0	13.3	16.1	18.4	17.3	15.3	11.9	7.8
1966	4.8	4.1	4.5	7.8	10.6	12.4	15.3	17.5	17.5	14.6	11.6	8.4
1967	5.9	5.7	5.0	6.8	10.1	13.3	16.1	18.5	18.2	15.4	11.3	7.2
1968	4.6	3.3	4.6	7.1	11.1	13.4	16.1	17.5	17.2	14.2	10.9	6.8
1969	2.4	1.5	3.4	7.2	10.8	14.6	17.1	18.2	17.7	14.8	11.5	7.6
1970	4.3	4.1	4.8	6.8	10.9	14.8	18.0	19.2	17.5	15.2	10.6	6.2
1971	4.0	3.5	3.6	6.6	10.7	12.6	15.3	18.4	17.2	15.2	11.3	6.8
1972	3.6	1.9	4.0	7.2	10.6	12.9	15.2	17.3	16.8	15.4	11.3	7.3

TABLE II.3-D-2

MONTHLY AVERAGE TEMPERATURES (°C) AT RICHLAND

Year	J	F	M	A	M	J	J	A	S	O	N	D
1965	6.1	5.4	6.3	9.1	11.0	14.2	17.3	19.8	18.5	16.4	12.6	8.4
1966	5.9	6.2	6.8	10.3	12.1	13.5	16.2	18.8	19.4	15.6	12.6	9.5
1967	7.4	7.0	6.6	8.8	12.0	13.9	17.0	20.2	19.4	16.1	12.0	7.8
1968	5.7	5.0	6.0	8.8	12.8	14.3	17.0	18.7	18.3	15.0	11.4	7.4
1969	2.7	1.9	4.3	8.0	11.4	15.3	17.9	19.3	18.6	15.2	11.7	8.0
1970	5.3	4.9	5.7	7.9	11.7	15.4	19.0	19.9	17.5	14.9	10.6	5.9
1971	4.2	3.4	3.8	7.0	11.1	12.9	16.4	19.5	17.8	15.0	10.7	6.2
1972	3.3	2.2	3.7	7.0	11.0	13.3	15.5	18.1	16.9	14.0	10.5	6.1
1973	3.2	3.0	4.7	7.8	12.9	15.6	18.3	19.6	18.3	15.0	9.9	

TABLE II.3-D-3

CHEMICAL ANALYSES AT PRIEST RAPIDS DAM; WATER YEAR OCTOBER 1971 TO SEPTEMBER 1972

DATE	TIME	INSTANTANEOUS DISCHARGE (cfs)	DISSOLVED CALCIUM (Ca) (mg/ℓ)	DISSOLVED MAGNESIUM (Mg) (mg/ℓ)	DISSOLVED SODIUM (Na) (mg/ℓ)	DISSOLVED POTASSIUM (K) (mg/ℓ)	BICARBONATE (HCO_3) (mg/ℓ)	ALKALINITY AS $CaCO_3$ (mg/ℓ)	DISSOLVED SULFATE (SO_4) (mg/ℓ)	DISSOLVED CHLORIDE (Cl) (mg/ℓ)	TOTAL KJELDAHL NITROGEN (N) (mg/ℓ)
OCTOBER											
11	1630	106000	19	4.2	2.2	1.0	74	61	12	1.5	0.12
18	1410	91600	19	4.2	2.4	3.1	73	60	13	2.0	0.13
NOVEMBER											
08	1410	101000	19	4.4	2.3	1.1	74	61	11	0.7	0.08
15	1300	104000	19	4.0	2.7	1.5	72	59	11	2.0	0.79
DECEMBER											
13	1515	146000	21	4.7	2.0	0.7	76	62	15	1.0	0.02
27	1340	132000	20	4.5	2.1	1.1	75	62	13	1.9	0.15
JANUARY											
24	1350	132000	21	4.9	2.3	0.8	79	65	14	1.1	0.12
FEBRUARY											
07	1335	107000	22	4.8	2.0	0.8	78	64	14	1.7	0.06
21	1350	135000	21	4.7	2.4	1.1	82	67	14	1.8	0.13
MARCH											
13	1410	172000	21	4.9	2.1	1.2	80	66	14	1.2	0.30
27	1430	151000	21	4.9	2.4	1.0	77	63	16	1.2	0.31
APRIL											
10	1440	215000	20	4.8	3.0	0.9	77	63	16	0.6	0.14
24	1325	136000	21	4.9	2.4	1.4	80	66	1.6	0.19	
MAY											
08	1425	175000	20	4.9	2.5	1.0	76	62	15	0.6	0.19
22	1340	314000	19	4.4	2.7	0.7	68	56	14	0.9	0.39
JUNE											
12	1410	404000	16	3.6	1.4	0.9	64	52	9.5	1.8	0.93
26	1435	410000	17	3.7	1.8	0.8	65	53	9.8	0.7	0.37
JULY											
10	1440	241000	17	3.6	1.3	0.7	56	46	16	1.0	0.84
24	1530	197000	18	3.8	1.6	0.8	64	52	8.6	1.0	0.16
AUGUST											
07	1500	180000	18	3.7	1.6	0.7	65	53	9.6	0.3	0.24
21	1440	144000	18	3.7	1.7	0.7	67	55	9.5	0.9	0.79
SEPTEMBER											
11	1410	131000	19	3.9	2.4	0.7	69	57	9.8	1.3	0.11
25	1510	92000	18	4.2	1.9	9.0	70	57	11	0.6	0.13

DATE	DISSOLVED NITRITE (N) (mg/ℓ)	AMMONIA NITROGEN (N) (mg/ℓ)	DISSOLVED NITRATE (N) (mg/ℓ)	DISSOLVED ORTHO PHOSPHORUS (P) (mg/ℓ)	TOTAL PHOSPHORUS (P) (mg/ℓ)	DISSOLVED SOLIDS (RESIDUE AT 180°C) (mg/ℓ)	HARDNESS (Ca, Mg) (mg/ℓ)	NON-CARBONATE HARDNESS (mg/ℓ)	SPECIFIC CONDUCTANCE (MICROMHOS)	pH (UNITS)
OCTOBER										
11	0.000	0.05	0.11	0.010	0.030	82	65	4	160	7.8
18	0.000	0.06	0.07	0.010	0.020	98	65	5	140	7.8
NOVEMBER										
08	0.000	0.01	0.16	0.020	0.030	90	66	5	145	7.7
15	0.010	0.21	0.31	0.020	0.050	88	64	5	145	7.8
DECEMBER										
13	0.010	0.01	0.20	0.010	0.030	92	72	9	151	7.4
27	0.010	0.00	0.25	0.020	0.030	88	68	7	148	7.6
JANUARY										
24	0.000	0.03	0.45	0.030	90	73	8	156	7.8	
FEBRUARY										
07	0.010	0.01	0.04	0.030	0.040	78	75	11	171	7.6
21	0.000	0.05	0.18	0.030	0.040	112	72	5	165	7.8
MARCH										
13	0.010	0.05	0.32	0.030	0.060	152	73	7	158	6.5
27	0.010	0.07	1.5	0.010	0.070	136	73	9	158	7.8
APRIL										
10	0.010	0.03	0.14	0.020	0.050	154	70	7	156	8.0
24	0.010	0.05	0.05	0.010	0.06C	130	73	7	159	8.0
MAY										
08	0.000	0.05	0.04	0.010	0.030	154	70	8	164	8.0
22	0.000	0.05	0.07	0.010	0.050	100	66	10	370	7.8
JUNE										
12	0.010	0.30	1.1	0.000	0.080	134	55	2	128	7.6
26	0.000	0.05	0.10	0.010	0.030	112	58	4	134	7.7
JULY										
10	0.000	0.18	0.15	0.010	0.030	112	57	11	150	7.6
24	0.010	0.02	0.22	0.000	0.020	70	61	8	135	8.1
AUGUST										
07	0.010	0.04	0.08	0.000	0.020	104	60	7	144	8.2
21	0.010	0.24	0.10	0.010	0.020	104	60	5	139	7.9
SEPTEMBER										
11	0.000	0.01	0.10	0.000	0.010	82	63	7	140	8.2
25	0.010	0.03	0.30	0.010	0.030	98	62	5	139	8.5

TABLE II.3-D-3 (Continued)

DATE	TEMPERATURE (DEG C)	COLOR (PLATINUM COBALT UNITS)	TURBIDITY (JTU)	DISSOLVED OXYGEN (mg/ℓ)	IMMEDIATE COLIFORM (COL. PER 100 ML)	DISSOLVED CHROMIUM (Cr) (μg/ℓ)	DISSOLVED COPPER (Cu) (μg/ℓ)	DISSOLVED LEAD (Pb) (μg/ℓ)	TOTAL MERCURY (Mg) (μg/ℓ)	DISSOLVED ZINC (Zn) (μg/ℓ)
OCTOBER										
11	17.9	9	4	9.9	100	-	-	-	---	--
18	15.1	26	2	10.0	2000	-	2	2	0.1	0
NOVEMBER										
08	10.5	12	2	10.8	>100	-	-	-	---	--
15	11.7	5	2	10.4	50	-	-	-	---	--
DECEMBER										
13	6.2	27	2	11.7	50	-	-	-	0.3	10
27	5.2	7	1	12.5	----	-	-	-	---	--
JANUARY										
24	3.0	8	2	13.2	----	0	1	2	1.1	20
FEBRUARY										
07	1.8	7	2	13.5	30	0	6	3	0.5	30
21	3.6	12	10	13.6	50	0	2	3	0.8	20
MARCH										
13	4.7	12	4	15.4	60	0	1	4	0.3	50
27	5.1	21	7	15.9	65	0	1	9	0.1	60
APRIL										
10	7.8	17	4	14.6	250	0	1	8	0.6	80
24	10.0	13	3	11.3	100	0	1	3	0.2	50
MAY										
08	9.4	12	4	13.3	130	0	1	5	0.0	40
22	11.7	21	9	13.8	400	0	1	5	0.3	50
JUNE										
12	13.1	33	29	13.0	400	0	9	76	5.3	40
26	13.6	16	5	12.8	200	0	2	6	0.7	50
JULY										
10	15.2	18	3	12.0	400	0	2	5	0.2	20
24	17.5	12	4	11.6	1300	0	2	5	0.8	20
AUGUST										
07	19.2	13	2	11.3	110	0	0	2	0.1	10
21	18.9	9	2	11.0	120	0	2	2	0.6	30
SEPTEMBER										
11	18.7	14	1	10.1	400	0	2	4	3.3	0
25	14.8	12	1	11.0	220	0	10	1	2.5	20

be studied by comparison analyses on river samples taken semimonthly at Vernita (upstream from reactors) and Hanford (downstream of reactors). Mean values for selected analyses for CY 1963 are given in Table II.3-D-4. Statistical comparisons of these data, using a t-test on the differences between means, showed no significant differences at the 90% confidence level in any of the species other than hexavalent chromium, used in reactor cooling water treatment. Similar data plus Si, Na, K, Zn, B, Mn, NH_4, NO_3, and turbidity for samples taken at Vantage and 100-F Area during 1962 and 1963 also showed no significant differences.

Table II.3-D-5[21] presents biological and chemical analyses on the Columbia River at Vernita and Richland for 1972. More complete data on a weekly basis are documented.[22]

TABLE II.3-D-4

COLUMBIA RIVER CHEMICAL CHARACTERISTICS (1963)

(All values in ppm)

	Ca	Mg	Cu	Fe	SO_4	Cl	PO_4
Vernita	21	3.9	0.0035	0.057	11.9	0.34	0.067
Hanford	21	3.7	0.0034	0.050	12.0	0.35	0.052

	M.O. Alk	Hardness	Total Diss. Solids	Diss. O_2	Cr^{+6}
Vernita	63	69	86	10.8	<0.005
Hanford	63	69	84	10.8	0.015

TABLE II.3-D-5

COLUMBIA RIVER BIOLOGICAL ANALYSES FOR 1972

	Coliform (N/100 ml)		Enterococci (N/100 ml)		BOD (ppm)	
	Vernita	Richland	Vernita	Richland	Vernita	Richland
# Samples	14	11	14	11	14	11
Max.	210.	460.	280.	88.	4.1	4.2
Min.	1.0	2.0	1.0	2.0	1.0	1.2
Avg.	49.	88.	37.	34.	2.6	2.9

COLUMBIA RIVER CHEMICAL ANALYSES FOR 1972

	Nitrate (NO_3) (ppm)		pH		Turbidity (JTU))		Dissolved O_2 (ppm)	
Water Quality Standard	45		6.5 to 8.5		5 + Bg		8.0 min.	
	Vernita	Richland	Vernita	300 Area	Vernita	300 Area	Vernita	300 Area
# Samples	51	52	47	224	48	219	34	181
Max.	1.3	1.0	9.2	9.4	28.	30.	13.6	14.7
Min.	(a)	0.14	7.4	7.2	0.6	0.05	4.0	8.1
Avg.	0.36	0.37	8.1	8.0	5.0	4.6	11.0	10.

(a) Less than the analytical limit of 0.1 ppm.

Sediments

From the reactors located on the Hanford Reservation to several miles below the Snake River mouth, bed sediments of the Columbia River are typically sand intermixed with gravel and rock as large as 8 inches in diameter. Streambeds of eddying areas in this relatively fast-water reach are usually composed of sand. Sand, silt, and clay are deposited in slack-water areas behind McNary Dam. Between the upstream reach (which has a coarse-sediment bed) and the deposits of small-size sediments near McNary Dam, the streambed in deep channels is sand and in shallow areas is a mixture of sand, silt, and some clay. Some sediment is present in the Bonneville reservoir. In general the bed in most stretches of the river between the reservoirs either has been scoured to bedrock or has been covered with a thin deposit of coarse gravel.

Concentrations of suspended sediment carried by the Columbia River vary considerably throughout the year because of the seasonal contributions of tributaries.[23] However, during all seasons the Snake River usually is the major contributor of suspended sediments. During slack water the dams along the Columbia and Snake Rivers normally interrupt the transport of suspended sediment as well as the bedload; during high water the sediment is resuspended. Thus, most of the suspended sediment is discharged to the Pacific Ocean during the late spring and early summer at the time of highest flow rate.

Bedload sediment transport, appreciable only in the lower Columbia, is probably small, perhaps on the order of 10% of the total sediment load exclusive of dissolved materials.[24]

Figure II.3-D-5[24] and Table II.3-D-6 give particle size data for eight of the reservoirs of the Columbia River, based on 152 samples from near the center of the channel. The reservoirs of importance here are Priest Rapids, Ice Harbor, McNary, The Dalles, and Bonneville. Table II.3-D-7[24] shows the mineral composition of the sediment while Table II.3-D-8 shows the chemical composition.

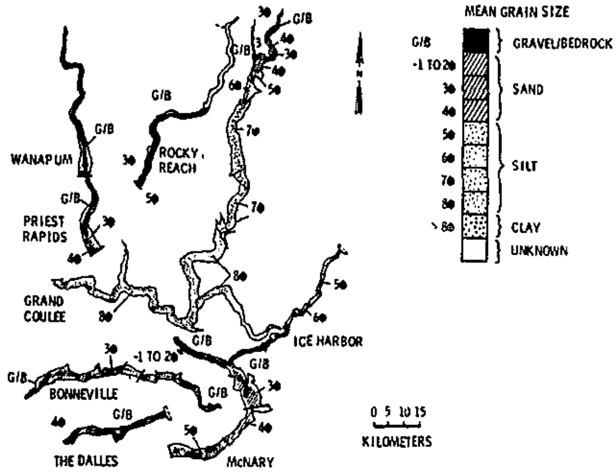


FIGURE II.3-D-5 PARTICLE-SIZE DATA FOR EIGHT OF THE RESERVOIRS OF THE COLUMBIA RIVER

TABLE II.3-D-6

PARTICLE-SIZE DISTRIBUTIONS OF UNDISPERSED AND DISPERSED SEDIMENTS FROM COLUMBIA RIVER SIZE CLASSES

Type of Analysis: A, not dispersed mechanically or chemically;
B, dispersed mechanically and chemically

(Size limits and range in microns)

Size Class Number and Limits	Location	Type of Analysis	Percent in Size Range 62-31	31-16	16-4	4-2	<2
8 (62-31)	Pasco	A	93.8	4.0	0.7	0.6	0.9
	McNary Dam	A	92.2	5.3	1.4	.1	1.0
	The Dalles	A	89.0	8.9	1.3	.1	.7
	Hood River	A	90.8	7.3	.5	.5	.9
	Hood River	B	86.4	9.5	1.4	1.1	1.6
	Bonneville Dam	A	92.8	5.2	1.3	.0	.7
	Vancouver	A	92.5	6.5	.6	.1	.3
	St. Helens	A	90.8	8.0	.8	.1	.3
8 (31-16)	McNary Dam	A	10.8	83.7	3.7	1.8	.0
	The Dalles	A	7.4	86.4	4.4	.5	1.3
	Hood River	A	9.8	84.1	5.5	.2	.4
	Bonneville Dam	A	12.3	82.7	3.6	.1	1.3
	Vancouver	A	8.7	85.4	5.2	.2	.5
	St. Helens	A	9.6	84.7	4.7	.3	.7
9 (16-4)	Pasco	A	.0	22.9	68.1	5.1	3.9
	McNary Dam	A	.0	11.0	84.6	1.1	3.5
	McNary Dam	B	.0	7.3	81.5	5.5	5.7
	The Dalles	A	.0	10.9	82.1	4.0	3.0
	Hood River	A	.0	.0	90.5	7.6	1.9
	Bonneville Dam	A	.5	9.1	85.1	2.5	2.8
	Vancouver	A	.0	8.8	83.7	3.9	3.6
	St. Helens	A	.0	5.1	87.4	.0	7.5
10 (4-2)	McNary Dam	A	.0	3.7	40.5	46.7	9.1
	McNary Dam	B	.0	.0	11.6	52.2	36.2
	The Dalles	A	.0	.0	24.3	60.4	15.3
	The Dalles	B	1.0	1.4	2.0	70.6	25.0
	Vancouver	A	.0	.0	32.0	56.3	11.7
11 (<2)	McNary Dam	A	.0	.0	.0	34.6	65.4
	McNary Dam	B	1.1	.2	13.8	10.3	74.6
	The Dalles	A	.0	.0	.0	30.1	69.9
	Hood River	A	.0	.0	.5	9.1	90.4
	Hood River	B	.0	.0	.7	10.1	89.2
	Vancouver	A	.0	.0	.5	19.7	79.8
	St. Helens	A	.0	.0	.0	6.1	93.9
	St. Helens	B	.0	.0	.1	7.9	92.0

TABLE II.3-D-7

MINERAL COMPOSITION OF BOTTOM SEDIMENTS FROM COLUMBIA RIVER RESERVOIRS

Bulk-Mineral Composition (in %) of Bottom Sediments from Columbia River Reservoirs Determined Petrographically by Point-Counting Thin Sections. Approximately 250 grains counted per sample. x=mean, s=standard deviation

Constituent	Bonneville		The Dalles		McNary		Priest Rapids Wanapum	Priest Rapids Rocky Reach	Grand Coulee		Ice Harbor	
	x	s	x	s	x	s	x	s	x	s	x	s
Quartz	29	9.0	29	9.3	34	9.0	41	6.5	37	10.4	45	5.2
Plagioclase	18	5.2	17	5.9	15	6.8	12	3.5	5	0.6	8	4.1
K-feldspar	10	4.[illegible]	13	6.6	12	5.1	11	2.7	12	9.9	11	3.9
Lithic fragments	35	12.5	32	20.4	29	11.9	21	10.9	28	9.3	16	7.5
Opaque minerals	4	4.5	5	2.9	4	3.2	13	5.3	15	2.7	3	1.5
Mafic minerals[a]	5	3.2	4	3.1	6	5.3	2	1.7	3	1.7	18	5.0
Number of Samples	19		6		15		12		3		19	

(a) Largely orthopyroxene (hypersthene), clinopyroxene (augite), hornblende, and biotite.

Heavy-Mineral (SG>3.17) Composition (in %) of Bottom Sediments from Columbia River Reservoirs Determined Petrographically by Point-Counting Grain Mounts in Hyrax (n=1.67). Approximately 250 grains counted per sample. x=mean, s=standard deviation

Constituent	Bonneville		The Dalles		McNary		Priest Rapids Wanapum	Priest Rapids Rocky Reach	Grand Coulee		Ice Harbor	
	x	s	x	s	x	s	x	s	x	s	x	s
Orthopyroxene[a]	27	10.0	10	7.3	6	3.2	5	2.4	5	3.5	2	1.5
Clinopyroxene[b]	38	9.1	47	9.8	30	7.7	20	10.1	14	3.5	12	6.0
Hornblende	22	11.9	32	9.9	44	10.0	58	13.1	57	3.6	72	7.8
Epidote	2	2.9	1	0.8	2	1.8	3	3.1	3	1.7	1	1.3
Garnet	6	5.2	6	3.3	9	6.8	7	4.5	9	7.0	4	2.8
Sphene	1	1.0	2	1.0	3	1.1	5	1.9	9	2.4	5	2.3
Zircon	1	1.3	1	1.0	4	4.5	2	1.5	3	1.3	3	1.7
Apatite	1	0.8	1	0.8	1	1.0	1	0.7	0		1	0.3
Other	tr		tr		tr		tr		tr		tr	
Number of Samples	19		6		15		12		4		9	

(a) Largely hypersthene.
(b) Largely augite.

TABLE II.3-D-8

CHEMICAL COMPOSITION IN BOTTOM SEDIMENTS FROM COLUMBIA RIVER RESERVOIRS

Chemical Composition of Major-Element Oxides (in weight %) in Bottom Sediments from Columbia River Reservoirs. Analysis by X-ray emission spectrography (MnO and TiO_2 by optical emission spectrography). x=mean, s=standard deviation

Constituent	Bonneville		The Dalles		McNary		Priest Rapids Wanapum	Priest Rapids Rocky Reach	Grand Coulee		Ice Harbor	
	x	s	x	s	x	s	x	s	x	s	x	s
SiO_2	68.5	4.3	65.2	3.4	67.6	4.8	66.2	3.3	58.4	2.9	62.3	2.[illegible]
TiO_2	0.8	0.2	0.8	0.1	0.8	0.2	0.7	0.2	0.8	0.1	1.1	0.1
Al_2O_3	13.3	1.1	14.1	1.4	13.6	0.8	14.4	0.8	17.0	1.9	14.9	1.4
FeO Fe_2O_3 as Fe_2O_3	5.1	1.3	5.7	0.9	4.8	1.3	3.3	0.8	5.1	0.6	4.6	0.7
MnO	0.1	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.2	0.[illegible]	0.3	0.4
MgO	2.1	0.5	2.1	0.2	1.8	0.4	2.1	0.4	2.6	0.5	2.1	0.2
CaO	3.2	1.0	3.7	0.5	3.2	1.0	3.5	0.3	2.6	0.3	3.[illegible]	0.9
Na_2O	3.0	0.2	2.7	0.3	2.8	0.3	3.5	0.3	2.5	0.2	2.[illegible]	0.2
K_2O	2.1	0.3	2.0	0.2	2.2	0.2	2.1	0.1	3.1	0.3	2.3	0.3
H_2O	nd		nd		nd		nd		nd		nd	
CO_2	nd		nd		nd		nd		nd		nd	
Total	98.2		96.4		96.9		95.9		92.3		94.2	
Number of Samples	21		11		15		12		6		9	

Chemical Composition of Minor Elements (ppm) in Bottom Sediments from Columbia River Reservoirs. Analysis by optical emission spectrography (E. Bingham, analyst). x=mean, s=standard deviation

Constituent	Bonneville		The Dalles		McNary		Priest Rapids Wanapum	Priest Rapids Rocky Reach	Grand Coulee		Ice Harbor	
	x	s	x	s	x	s	x	s	x	s	x	s
B	20	<5	20	<10	30	10	30	<10	50	<10	30	<10
Ba	1720	430	1600	270	1410	330	860	60	970	190	860	90
Co	10	<10	10	<10	10	<10	10	<10	20	<10	20	<10
Cr	50	10	50	<10	50	20	40	10	40	10	30	<10
Cu	20	10	40	10	40	10	40	10	90	20	50	10
Ga	20	<10	20	<10	20	<10	20	<10	20	<10	20	<10
Ni	30	10	30	<10	30	<10	40	10	50	10	30	<10
Pb	20	<10	40	20	40	20	70	50	570	170	30	10
Sc	20	<10	20	<10	20	<10	20	<10	20	<10	30	<10
Sr	430	70	430	80	450	110	360	110	280	30	300	50
V	90	50	120	30	60	50	100	40	90	10	130	30
Y	40	<10	50	10	50	10	50	10	120	20	60	<10
Zr	150	40	180	40	190	50	190	40	180	30	280	90
Number of Samples	21		11		15		12		6		9	

II.3-D.2.2 The Yakima River

The Yakima River, a small river with flows of between 1,300 cfs and 20,000 cfs, partially borders the Hanford Reservation on the southern side. This river is of minimal importance to the Hanford Reservation and its operation; i.e., no direct withdrawal or disposal is made to the Yakima River.

Continuous flow data[4] in the vicinity of Hanford are available from a water stage recorder located at Kiona (approximately 20 miles west of Richland). Data from this station show a maximum flow of 67,000 cfs on December 23, 1933 and a minimum of 105 cfs on September 11, 1906. For 1972 the maximum and minimum flows were 20,200 cfs and 1,420 cfs respectively; the mean flow was 6,700 cfs. Water quality for the Yakima River at Kiona, Washington, is summarized in Tables II.3-D-9[20] and II.3-D-10. Table II.3-D-9 presents the chemical analyses and specific conductance while Table II.3-D-10 contains temperature data for 1972.

II.3-D.2.3 Ponds

The Hanford Reservation contains man-made ditches and ponds which are used for the disposal of radioactive liquid waste, other industrial waste, and cooling waters from various processes.

TABLE II.3-D-9

YAKIMA RIVER CHEMICAL ANALYSES, WATER YEAR OCTOBER 1971 TO SEPTEMBER 1972, AT KIONA, WASHINGTON

DATE	TIME	INSTANTANEOUS DISCHARGE (cfs)	DISSOLVED CALCIUM (Ca) (mg/ℓ)	DISSOLVED MAGNESIUM (Mg) (mg/ℓ)	DISSOLVED SODIUM (Na) (mg/ℓ)	DISSOLVED POTASSIUM (K) (mg/ℓ)	BICARBONATE (HCO_3) (mg/ℓ)	ALKALINITY AS $CaCO_3$ (mg/ℓ)
OCTOBER								
05	1015	2320	29	11	20	2.9	160	131
19	0935	2820	27	10	17	3.3	151	124
NOVEMBER								
16	0940	2900	---	---	---	---	---	---
DECEMBER								
07	1055	2840	23	8.7	18	2.9	132	108
14	1105	2860	22	8.3	15	2.3	120	98
JANUARY								
10	1125	3080	19	8.0	14	2.9	114	94
FEBRUARY								
01	1105	4340	16	6.6	10	2.2	97	80
08	1115	4340	16	6.0	9.3	1.7	89	73
22	1315	7220	14	5.4	8.1	1.9	82	67
MARCH								
14	1120	17200	11	3.7	5.5	1.8	67	55
APRIL								
04	0915	17000	10	3.8	5.7	1.4	59	48
11	1055	15200	9.7	3.9	5.4	1.2	62	51
18	1125	11800	11	3.6	5.4	1.2	59	48
MAY								
10	1010	12800	12	4.1	5.9	1.4	66	54
23	1425	16100	12	4.2	5.9	1.3	64	52
JUNE								
13	1500	11600	13	4.2	6.8	1.5	72	59
27	1435	9450	13	4.4	6.9	1.4	73	60
JULY								
11	1715	2510	26	8.4	15	3.2	148	121
25	1540	1640	29	10	18	3.1	152	125
AUGUST								
08	1430	1470	30	11	20	3.7	167	137
22	1315	2320	26	9.7	17	3.3	150	123
SEPTEMBER								
12	1320	2280	27	10	18	2.9	140	122

TABLE II.3-D-10

TEMPERATURE (°C) OF WATER, WATER YEAR OCTOBER 1971 TO SEPTEMBER 1972
OF YAKIMA RIVER AT KIONA, WASHINGTON

DAY	OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER
1	11.5	6.0	6.0	3.5	0.0	4.5	8.5	9.0	15.0	18.5	24.5	18.5
2	13.0	6.0	6.0	2.0	0.0	4.5	8.5	10.0	16.5	18.0	20.5	18.5
3	15.0	6.5	6.0	0.5	0.0	1.0	7.0	10.0	16.5	18.5	21.0	19.0
4	14.0	8.5	5.0	1.0	0.0	2.0	7.0	11.5	16.0	18.5	21.0	19.0
5	15.0	6.5	4.5	1.0	0.0	6.0	8.5	15.0	14.5	19.0	21.0	19.0
6	15.0	5.5	4.5	1.5	0.5	4.5	8.5	13.5	18.0	20.0	21.0	17.0
7	14.5	6.0	4.0	2.0	0.5	4.5	8.0	14.5	20.5	20.0	21.5	18.5
8	14.5	5.5	1.5	1.0	1.0	4.5	8.0	12.0	16.5	19.0	22.0	16.5
9	15.0	5.5	3.0	1.0	0.5	4.5	7.0	11.5	17.0	19.5	26.0	16.0
10	15.0	7.0	3.0	0.0	1.0	7.0	6.0	10.0	15.5	18.0	22.0	16.5
11	15.0	7.0	5.0	3.5	1.5	7.0	7.0	11.0	14.5	16.5	25.0	15.0
12	14.0	8.5	0.0	4.0	4.0	8.0	8.5	12.0	13.5	18.0	20.5	15.0
13	11.5	6.0	0.5	3.0	4.0	7.0	6.0	15.0	14.0	19.5	21.0	14.5
14	12.0	9.5	0.0	1.5	3.5	7.0	9.5	----	14.5	20.5	20.0	15.0
15	11.5	6.0	2.0	0.5	4.0	6.5	9.0	14.0	16.5	20.5	20.0	16.0
16	11.5	8.0	3.0	0.0	4.5	7.0	9.5	12.0	16.0	19.5	19.5	16.0
17	7.0	6.5	4.0	2.0	4.5	5.5	6.5	11.0	15.5	20.0	17.0	17.0
18	9.0	6.0	4.5	3.0	4.0	6.0	9.0	10.0	15.5	20.0	18.5	16.0
19	10.0	6.0	4.0	3.5	4.0	9.5	8.0	10.5	15.5	19.5	18.0	14.5
20	9.5	7.0	4.0	5.5	5.0	8.0	10.0	13.5	16.0	19.0	18.5	13.5
21	9.5	5.0	4.5	5.0	4.5	5.0	8.5	13.5	16.0	18.0	18.5	14.0
22	10.0	6.0	4.5	5.5	4.5	8.5	7.0	11.5	16.5	19.5	21.5	12.0
23	10.5	6.0	4.5	4.0	4.5	6.5	9.5	11.0	14.5	21.0	19.0	11.5
24	10.0	6.0	4.5	3.0	4.5	6.5	8.0	11.5	14.0	20.0	----	12.0
25	10.0	6.0	4.5	1.6	4.0	6.0	9.0	11.0	14.0	19.0	19.5	10.5
26	9.0	---	3.5	0.0	4.5	6.0	8.5	11.5	15.5	20.5	20.0	----
27	9.0	6.0	1.5	0.0	6.0	6.5	9.5	14.0	15.0	20.5	21.0	10.5
28	7.0	7.0	1.0	0.0	7.0	5.5	10.0	15.0	16.0	20.5	21.0	10.5
29	6.0	6.5	1.5	0.5	5.5	6.5	10.0	16.5	17.0	25.0	21.0	11.0
30	6.0	6.5	1.0	-0.5	---	6.5	10.0	18.0	18.0	26.0	20.5	----
31	6.0	---	1.0	---	---	7.0	----	17.0	----	22.0	19.5	----
MONTH	11.0	6.5	3.5	1.0	3.0	6.0	8.5	12.5	16.0	20.0	20.5	15.0

No routine chemical or temperature measurements are made of these disposal sites. These sites, shown in Figure II.3-D-2, are listed in Appendixes II.1-B, C and E with detailed inventory data. In addition to these artificial ponds, one natural pond exists, West Lake (Figure II.3-D-2). The size of this pond is a direct function of the elevation of the groundwater in that area; its average size is about 10 acres.

In the event that a pond is no longer used (and hence dries up), it is covered with surrounding sand and soil by a bulldozer. This action prevents any wind transport of nuclides contained in the pond's sediments.

II.3-D.3 The Unsaturated Zone [X.18]

II.3-D.3.1 Description

The unsaturated (vadose) zone has been defined by the U.S. Geological Survey's Committee on Redefinition of Ground-Water Terms[26] as:

> ". . . the zone between the land surface and the water table. Characteristically, this zone contains liquid water under less than atmospheric pressure, and water vapor and air or other gases usually at atmospheric pressure. In parts of this zone, interstices may be temporarily or permanently filled with water. Perched water bodies may exist within the unsaturated zone."

Perched groundwater is defined[26] as:

> ". . . unconfined groundwater separated from an underlying body of groundwater by an unsaturated zone."

On the Hanford Reservation, the thickness of the unsaturated zone varies from less than one foot to more than 350 feet. Geologic cross sections are presented in Figures II.3-D-6 and II.3-D-7 showing the rock types beneath the Hanford Reservation and specifically the sedimentary materials within the unsaturated zone.[27,28] (The definition of the various sedimentary materials described in this section are those adopted by the National Research Council.[30]) The four distinct rock units present are, in ascending order, the Columbia River Basalt, the Ringold Formation, the Palouse Soil and a thick deposit of fluviatile and glaciofluviatile sediments.

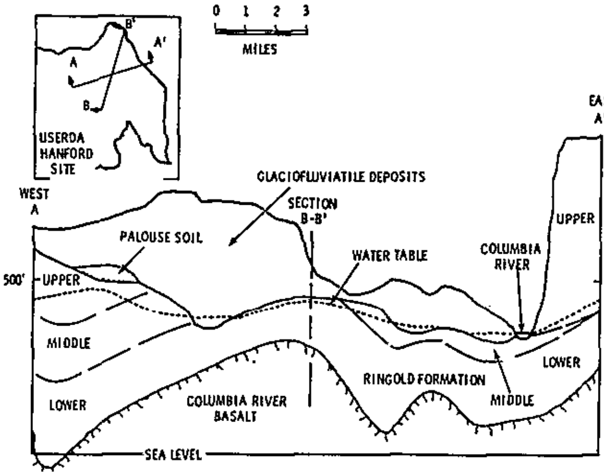


FIGURE II.3-D-6 GEOLOGIC CROSS SECTION, WEST TO EAST

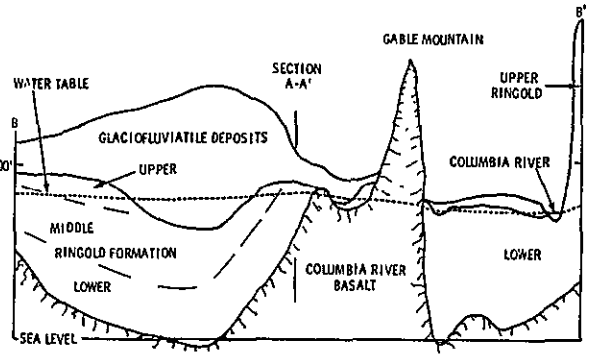


FIGURE II.3-D-7 GEOLOGIC CROSS SECTION, SOUTHWEST TO NORTHEAST

The Columbia River basalt forms the bedrock everywhere beneath the Hanford Reservation. The basalt rock lies within the unsaturated zone in several locations. In general, these areas are about one mile north and south of the 200 Areas.

Overlying the basalt bedrock is a lacustrine and fluviatile deposit known as the Ringold Formation. This formation is composed of silt, sand, gravel, and clay with some beds of volcanic ash present. These sediments were deposited in a shallow lake formed during the period when the Columbia River was impounded by the uplift of the Horse Heaven Hills. The Ringold Formation is more than 1,200 feet thick. However, south and west of the Columbia River more than 600 feet of these sediments have been eroded away. In some locations, the surface of the Ringold Formation is capped by a relatively thick accumulation of caliche (calcium carbonate). The Ringold Formation characteristically contains clays in the lower portion, locally consolidated and semi-consolidated silts, sands and gravels in the middle portion, and silts and sands in the upper portion. Sediments in all three zones of the Ringold Formation occur within the unsaturated groundwater zone (Figures II.3-D-6 and II.3-D-7).

Overlying the Ringold Formation in the western part of the Reservation is a bed of fine sand and silt up to 60 feet thick. Believed to be of eolian (deposited by wind) origin, this deposit is locally called Palouse Soil because of its similarity in grain size and heavy mineral composition to the eolian Palouse soil of eastern Washington and western Idaho.[31] The Palouse Soil lies completely within the unsaturated zone (Figure II.3-D-6).

Glaciofluviatile sediments, deposited during late Pleistocene and Holocene, overlie the Ringold Formation and the Palouse Soil. These materials are heterogeneous and range in size from clay to boulders (Table II.3-D-11) although lenses of well-sorted materials are also present.

When the glaciofluviatile sediments were deposited on the Hanford Reservation (about 18,000 years ago), the area was completely covered by a lake (700 feet deep at the southern boundary of the Reservation).[32] Since the glaciofluviatile sediments were deposited, the water table underlying the region has remained in essentially the same position as it does today. Most of the glaciofluviatile sediments lie within the unsaturated zone (Figures II.3-D-6 and II.3-D-7).

The movement of water in the unsaturated zone is influenced by the physical properties of the sediments in two ways: 1) the size and structural arrangement of the sediment particles determine the space configuration through which the water moves, and 2) the interaction between the sediments and the water gives rise to water-moving forces. In sediments where pores are completely filled with water, the fluid is a single phase.[33] Where water does not completely fill the pores, the water potential depends on the gravitational field and on the absorptive forces associated with the interfacial boundaries in the sediments. Where air partially fills the soil pores, with water occupying the remaining void space, a two-phase flow can take place. As the percentage of liquid water decreases, it occupies the smaller and smaller capillaries that exist between soil particles. The measurement of the capillary forces versus the degree of saturation can be plotted. A typical curve, shown in Figure II.3-D-8, shows that under the normal pressures existing in the ground, some liquid water is always present in the sediments.

Archeologists, working in the Columbia Plateau Province, have determined that the climate began to change about 8,000 years ago.[35] A warming trend occurred, reaching a climax about 4,000 years ago. During this period, the climate was warmer and more arid than it is today.[36] The sediments within the unsaturated zone are believed to be in equilibrium with the prevailing climatic conditions.

TABLE II.3-D-11

GRAIN-SIZE DEFINITIONS OF SEDIMENTARY MATERIALS AS USED IN THIS STATEMENT AND IN COMMON USAGE IN HANFORD GEOLOGIC RESEARCH[30]

DESCRIPTION	SIEVE SIZE - IN.[(a)]		
Very fine clay	0.0000096	to	0.000019
Fine clay	0.000019	to	0.000038
Medium clay	0.000038	to	0.000077
Coarse clay	0.000077	to	0.00015
Very fine silt	0.00015	to	0.00031
Fine silt	0.00031	to	0.00062
Medium silt	0.00062	to	0.0013
Coarse silt	0.0013	to	0.0025
Very fine sand	0.0025	to	0.0049
Fine sand	0.0049	to	0.0098
Medium sand	0.0098	to	0.0197
Coarse sand	0.0197	to	0.0394
Very coarse sand	0.0394	to	0.079
Very fine gravel	0.079	to	0.157
Fine gravel	0.157	to	0.315
Medium gravel	0.315	to	0.630
Coarse gravel	0.630	to	1.26
Very coarse gravel	1.26	to	2.52
Small cobbles	2.52	to	5.04
Large cobbles	5.04	to	10.08
Small boulders	10.08	to	20.16
Medium boulders	20.16	to	40.31
Large boulders	40.31	to	80.63
Very large boulders	80.63	to	161.3

(a) Reference includes sizes in millimeters.

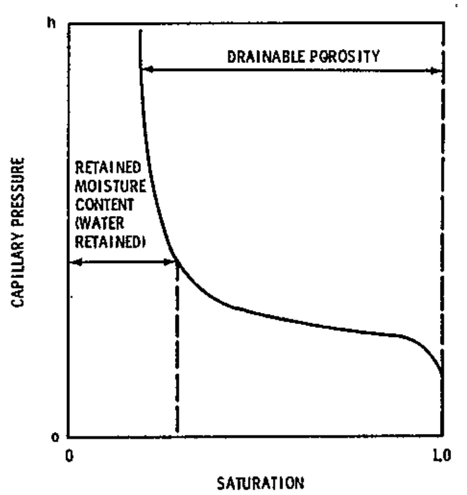


FIGURE II.3-D-8 SATURATION AS A FUNCTION OF CAPILLARY PRESSURE

The average annual precipitation at Hanford is about six inches per year, as shown in Figure II.3-D-9, while the total annual rainfall ranges from about three inches to about eleven inches.[36] Residual moisture in the Hanford sediments below a depth of 30 feet ranges from about 1.5% to about 4% with a mean value of about 2%, by weight.[34] Water content retained by capillarity ranges from 4% to 5%, by weight. Based on these data, a full year of precipitation of six inches would satisfy the sediment moisture deficiency to a depth of less than 24 feet if no loss to the atmosphere or redistribution other than capillary transport occurred.

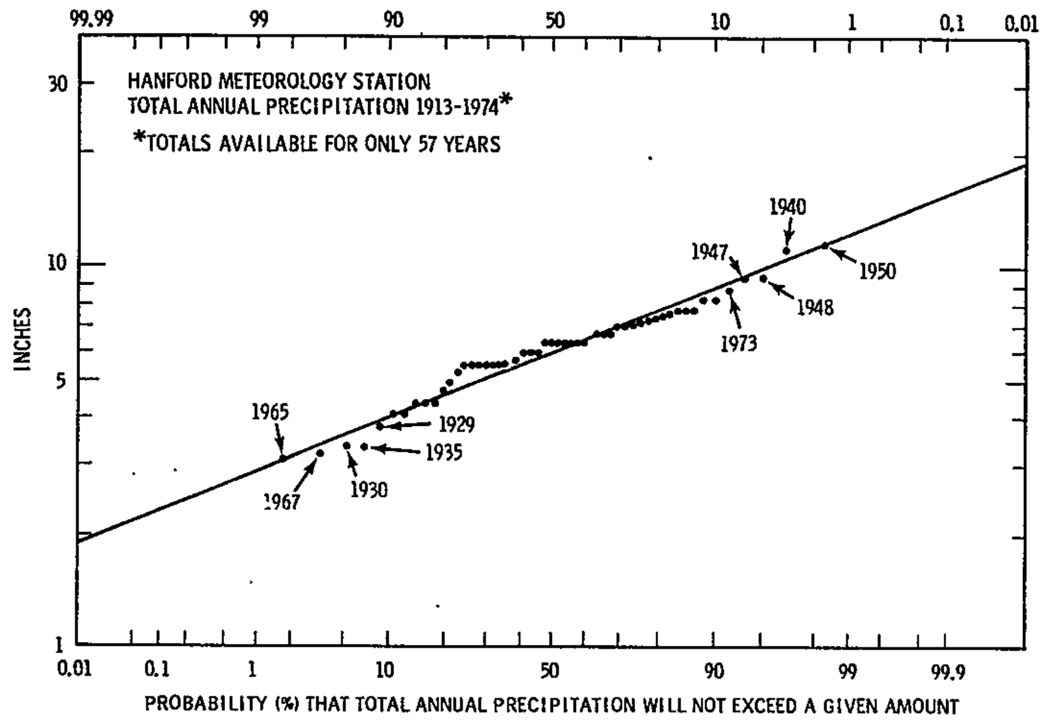


FIGURE II.3-D-9 TOTAL ANNUAL PRECIPITATION (1913-1974) FOR THE 200 AREA PLATEAU AT HANFORD RESERVATION

The probable maximum 24-hour precipitation (PMP) that can be expected in a region at least once in a million years can be estimated using a method developed by the Department of Commerce Weather Bureau.[37] A PMP value of 11 inches for the Hanford region was calculated, based on nearly 60 years of recorded rainfall data.

During the latest rain year (August 1, 1973 through July 31, 1974), Hanford experienced 170% of normal rainfall. At a field test site located south of the 200 East Area, rainfall moisture penetration is measured. The 170% of normal rainfall penetrated less than 18 feet into the sediments. All moisture from rainfall during the last rain year appears to have now evaporated to the atmosphere. In fact, the data indicate that more moisture has evaporated from the ground than was put in by rainfall during the last rain year. The current lysimeter data show that Hanford sediments, below a depth of about 30 feet, are extremely dry. In this desiccated zone, the ability of the sediments to transmit water is significantly reduced. A typical plot of hydraulic conductivity versus capillary pressure would look like that shown in Figure II.3-D-10. The forces necessary to cause moisture to move through sediments become larger as saturation decreases. In the desiccated zone, the capillary pressure is more than 10 negative atmospheres of pressure (10,000 mb). The hydraulic conductivity is so low that gravity is not the controlling force moving sediment moisture. The amount of water retained in the capillaries at equilibrium is a function of 1) the physical and chemical nature of the porous media, 2) the position of the porous media in a gravitational field with respect to a free water surface, 3) temperature, 4) pressure, 5) relative humidity, and 6) direction of approach to equilibrium. Thus, theoretically, any porous medium at equilibrium, following drainage, has some capacity for water retention against vaporization and against gravitational attraction to a free water table.

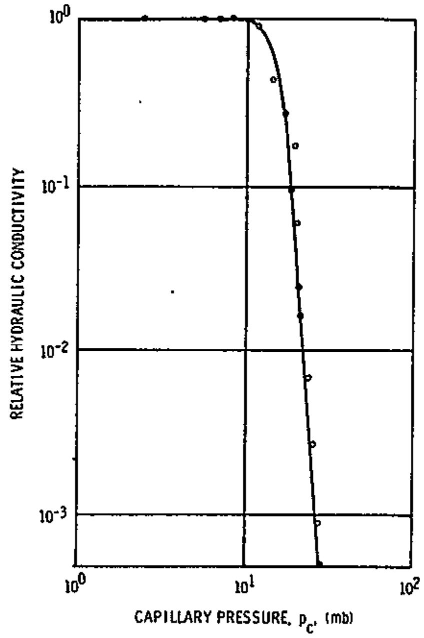


FIGURE II.3-D-10 RELATIVE HYDRAULIC CONDUCTIVITY AS A FUNCTION OF CAPILLARY PRESSURE

Practically, measurement of the specific retention capacity of sediments is difficult because under most conditions, water movement in sediments is exceedingly slow and equilibrium can be achieved only after extremely long periods of time. Thus, the specific-retention capacities measured for the sediments in the unsaturated zone represent the equilibrium conditions reached over the past several thousand years. The presence of the desiccated zone at the 30-foot depth in the region of the 200 Areas indicates that no moisture is moving downward from the ground surface (at the 200 Area test site) to the water table.

Several attempts have been made to measure drainage and water retention properties of the Hanford sediments using tensionmeters or suction plates. Whereas, these techniques are suitable for establishing irrigation and drainage practices for agricultural purposes, the techniques did not provide sufficient sensitivity for measuring moisture transport in sediments which contained about 1.5% to 3.0% water, by weight. Initial studies raised perplexing questions about the physical processes that affect moisture movement in these arid sediments. For example, estimates from laboratory data for Hanford-type sediments predicted that perhaps as much as ten inches of water could percolate to the water table in a year. Such quantities appear to be unrealistic and a more extensive understanding of moisture movement is warranted. Transport mechanisms previously thought to be of minor significance for sediment moisture transport such as vapor phase transport influenced by gravity, capillarity, thermal gradients, temperature-induced buoyancy, evapotranspiration and barometric compression and expansion are now believed to be the primary mechanisms controlling moisture movement through sediments in arid and semi-arid regions. Several additional mechanisms being studied to determine their significance include transport due to electrical gradients and freezing at the ground surface.[41-43] Several investigators[44-49] have studied the movement of moisture in the unsaturated zone. The geologic and climatic setting of these studies differ significantly from those on the Hanford Reservation, thus limiting their applicability in characterizing moisture movement in Hanford sediments.

The first major attempt to establish whether or not meteoric water percolates to the water table underlying the 200 Areas involved the use of thermocouple psychrometers. It was proposed that because water migrates from a high water potential to a lower potential, the potential gradient, i.e., the slope of the water potential curve versus depth, could be used to establish the direction of water transport as well as the magnitude of the driving force (isothermal condition).

In tests based on natural rainfall conditions, two lysimeters were constructed about one mile south of the 200 East Area. The two lysimeters have a diameter of 10 feet and a depth of 60 feet. The three sets of instrumentation provided for each lysimeter include: 1) a 1.5 inch aluminum alloy tube for use with a Nuclear of Chicago neutron log sensor, 2) a set of thermocouple psychrometers with temperature sensors attached, and 3) a stainless tube for recording pore pressure as a function of time and depth. One lysimeter has an open bottom; the other is closed. The purpose of closing the bottom of one lysimeter is to provide a more complete definition of the column of sediments within it by isolating it from complicating factors such as the effects of changing atmospheric perssures and vapor migration. The closed-bottom lysimeter would serve as a container to collect water if precipitation does indeed percolate to the water table on the 200 Area plateau. If, on the other hand, evaporation exceeds percolation, the bottom zone of the closed-bottom lysimeter would slowly lose moisture. Thus, as the lysimeter begins to equilibrate, changes in the psychrometer readings and the direction of changes will predict whether or not percolation occurs. The observation has been made with the closed-bottom lysimeter during the 1973-1974 water year that a higher than average rainfall (170% of normal) reached a depth of 4 meters and then was removed by summer heat.

The Continuum Mechanics Flow Model defines a set of coupled flow equations capable of describing movement in the water phase, compressible moist air phase, and vapor component.

The basic equations are developed using continuum mechanics to describe the energetics of the system. Through the energy equations which involve heats of vaporization and condensation, vapor fluxes were incorporated to build still more general dynamic equations.[51] The final dynamic equations obtained included the combined effects of liquid, vapor, gas and temperature-induced-flow mechanisms. The fluxes obtained are:

- for the liquid phase:

$$\underline{q_l} = -\frac{k_l}{\mu_l}\left(-\rho_l \underline{g} + \nabla p_l\right)$$

where

$\underline{q_l}$ = liquid flux rate of water

$k_l = k_l\,(P_c)$ is the capillary conductivity of the liquid water phase

$\rho_l = \rho_l\,(T)$ is the mass density of water

$\mu_l = \mu_l\,(T)$ is the dynamic viscosity of the liquid water

$p_l = p_l\,(z, T)$ is the pressure in the liquid water phase

P_c = capillary pressure

$\underline{g}$ = gravitational constant vector

T = temperature

- for the compressible moist air phase:

$$\underline{q_2} = -\frac{k_2}{\mu_2}\left(-\rho_2 \underline{g} + \nabla p_2\right)$$

where

q_2 = flux rate of the moist air

$k_2 = k_2\ (P_c)$ is the capillary conductivity of the air phase

$\rho_2 = \rho_2\ (T,\ p_2)$ is the mass density of the moist air phase

$\mu_2 = \mu_2\ (T)$ is the dynamic viscosity of the gaseous mixture

$p_2 = p_2(z,t)$ is the pressure of the air-vapor mixture .

and the other terms are as previously defined.

- for the water vapor component phase:

$$q_3 = - D_T\ (1-S_1)\ \nabla T - D_p\ (1-S_1)\ \nabla p_1 - \Omega_3\ \frac{k_2}{\mu_2}\ (\nabla p_2 + \rho_2 \underline{g})$$

where

$\underline{g}_3$ = flux rate of the water vapor component in the gas phase

$D_T = D_T\ (p_3,T)$ is the temperature-related transport coefficient for vapor

$D_p = D_p\ (p_3,T)$ is the pressure-related transport coefficient for the vapor

$\Omega_3 = \Omega_3\ (p_2,p_3,T)$ is the coefficient for the partial fraction of the vapor

$p_3 = p_3\ (z,T)$ is the vapor partial pressure

S_1 = liquid water saturation

and the other terms are as previously defined.

II.3-D.3.2 Liquid Waste in the Unsaturated Zone [X.24]

Liquid waste containing radionuclides has been discharged into the ground under controlled conditions for over 25 years. Controls consisted of 1) evaluating the radionuclide-sediment reactions prior to and during discharge, 2) conditioning of the waste liquid, as necessary, to enhance the sorption of long-lived radionuclides (principally, ^{90}Sr, ^{137}Cs, and ^{239}Pu); and 3) surveillance of the radionuclides in the sediments. Experience and knowledge gained from this waste management practice have shown that essentially all of the strontium and cesium are sorbed on the sediments above the regional water table in the unsaturated zone.[52] Although most ^{90}Sr is sorbed by the sediments prior to reaching groundwater, trace amounts do enter the underlying groundwater flow system. However, even these small quantities are diluted and sufficiently decayed prior to entering public water supplies. Plutonium usually precipitates as an insoluble phase in the calcareous Hanford sediments.[52] Data from both laboratory tests and field studies show that radionuclides retained in the vadose zone exhibit a chromatographic-like distribution. On the other hand, tritium moves essentially with the waste liquid with very little if any sorption. Ruthenium is held relatively well, but a small fraction of the ruthenium is of such ionic form that little sorption takes place.

Of the more than 180 cribs located in the 200 Area Control Zones, 42 cribs were identified with quantities of ruthenium, strontium, and cesium in the lowermost 50 feet of the unsaturated zone. The quantity of ruthenium, strontium and cesium in each 10-foot increment above the present water table was calculated using an empirically-derived expression. The inventory calculated for the lowermost 50 feet of the unsaturated zone was about 2,000 curies of ruthenium and about 400 curies of strontium plus cesium.

During the past several years, a number of proposals have been made for use of land on the Hanford Reservation wherein ponding of large volumes of water or irrigation would be involved. The effects of such practices could result in a rise of the water table beneath the 200 Area Control Zone. Because sorption reactions are reversible, the radionuclides now retained on the sediments in the unsaturated zone could migrate if subjected to a continual flow of water. For these reasons, attention has been focused on the inventory of long-lived radionuclides that could be inundated in the sediments above the present water table. Any action that would result in raising the groundwater levels will be thoroughly evaluated prior to adoption.

There is evidence to support the concept of radionuclide migration upward toward the ground surface during periods of hot weather. Moisture in the upper ten to twenty feet of sediment can be pulled upward by capillary forces until it lies within a few feet of the ground surface. At this point, the water evaporates and moves out of the ground as water vapor. The radionuclides remain behind in the sediments near the ground surface.

II.3-D.4 The Unconfined Aquifer

II.3-D.4.1 Description

An unconfined aquifer has a water table serving as its upper boundary and can be recharged directly from the ground surface except where localized impervious layers overlie the water table. The water table, a surface at atmospheric pressure, marks the boundary between the saturated groundwater zone and the overlying unsaturated sediment.

The unconfined aquifer underlying the Hanford Reservation is defined as the saturated sediment lying between the water table and the first thick impermeable bed below the water table. The saturated interval lies partly in sediments of the Upper Ringold Formation and in other places in mostly fluviatile and glaciofluviatile sands and gravels. Table II.3-D-12[54] shows the major geologic units in the Hanford region and their water-bearing properties. Following the definition above, the bottom of the aquifer was determined using driller logs available throughout the Reservation (Figure II.3-D-11).

TABLE II.3-D-12[54]

MAJOR GEOLOGIC UNITS IN THE HANFORD REGION AND THEIR WATER-BEARING PROPERTIES

System	Series	Geologic Unit	Material	Water-Bearing Properties
Quaternary	Pleistocene	Fluviatile and glaciofluviatile sediments and the Touchet Formation. (0-200 ft thick)	Sands and gravels occurring chiefly as glacial outwash. Unconsolidated, tending toward coarseness and angularity of grains, essentially free of fines.	Where below the water table, such deposits have very high permeability and are capable of storing vast amounts of water. Highest permeability value determined was 12,000 ft/day.
		Palouse Soil (0-40 ft thick)	Wind deposited silt.	Occurs everywhere above the water table.
		Ringold Formation (200-1,200 ft thick)	Well-bedded lacustrine silts and sands and local beds of clay and gravel. Poorly sorted, locally semi-consolidated or cemented. Generally divided into the lower "blue clay" portion which contains considerable sand and gravel, the middle conglomerate portion, and the upper silts and fine sand portion.	Has relatively low permeability; values range from 1 to 200 ft/day. Storage capacity correspondingly low. In very minor part, a few beds of gravel and sand are sufficiently clean that permeability is moderately large; on the other hand, some beds of silty clay or clay are essentially impermeable.
	Miocene and Pliocene	Columbia River basalt series (>10,000 ft thick)	Basaltic lavas with interbedded sedimentary rocks underlie the unconsolidated sediments.	Rocks are generally dense except for numerous shrinkage cracks, interflow scoria zones, and interbedded sediments. Permeability of rocks is small (e.g., 0.002 to 9 ft/day) but transmissivity of a thick section may be considerable (70 to 700 ft^2/day)
?	?	Rocks of unknown age, type, and structure.		?

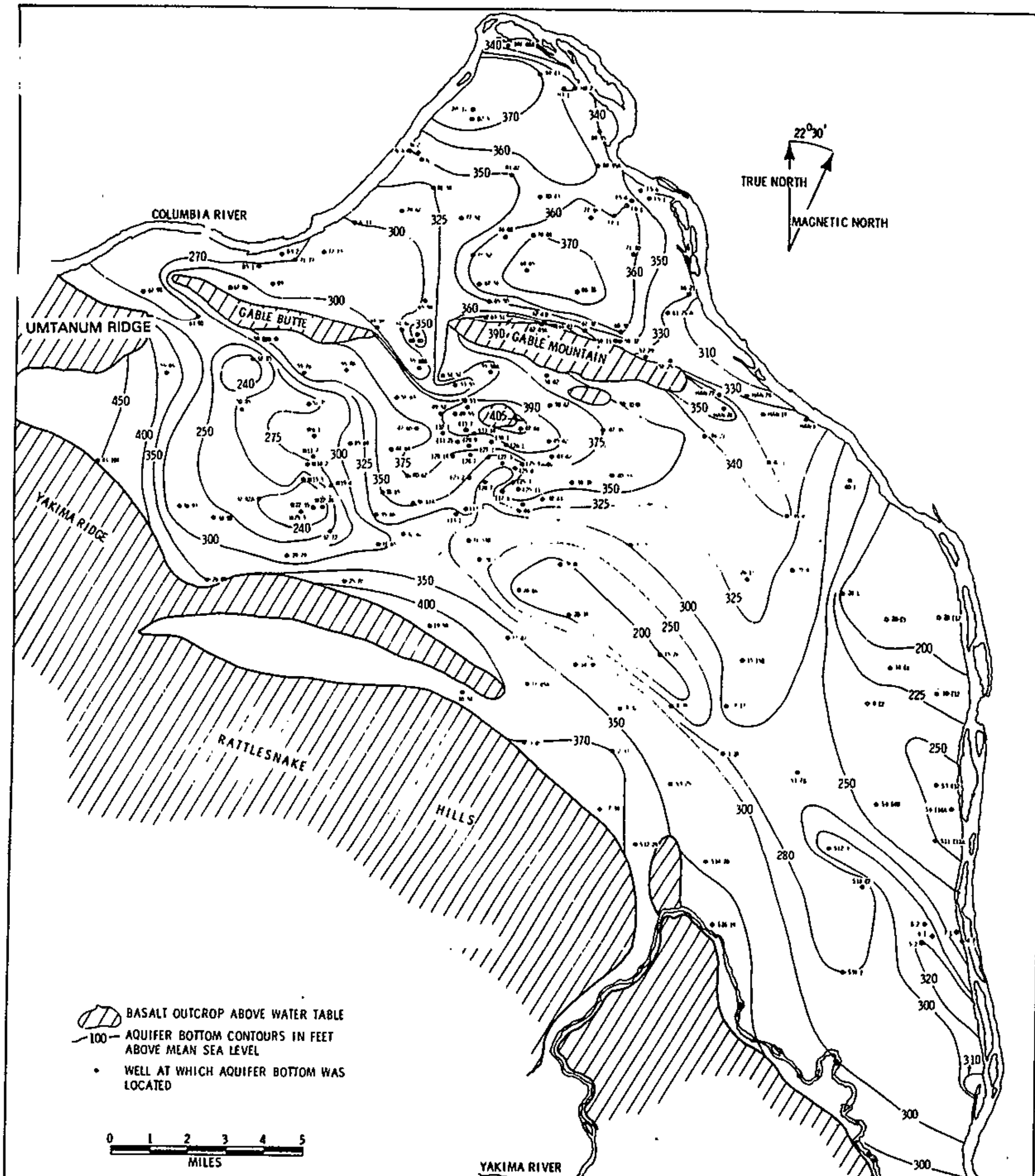


FIGURE II.3-D-11 HANFORD RESERVATION UNCONFINED AQUIFER BOTTOM MAP FOR SIMULATION MODEL

Descriptions of the geologic characteristics of the formations that make up the unconfined aquifer have been published.[55] The Ringold Formation occurs only in the Pasco Basin. Its age is controversial; it may be as old as mid-Pliocene or as young as mid-Pleistocene. The Ringold Formation has been described[55] as follows:

"Overlying the basalt bedrock of the Pasco Basin are sedimentary strata consisting largely of silt, sand, gravel, and volcanic ash. One prominently stratified part of that sedimentary cover is known as the Ringold Formation.

"The type locality of the Ringold Formation is in the White Bluffs, against which the Columbia River impinges in the northeastern part of the reservation and along the east side of the reservation. The strata at this locality are the only ones to which the name Ringold Formation was originally applied. The subsurface continuation of these strata, in places completely down to the underlying basalt, was also considered to be Ringold Formation.

"With the exception of a conglomerate train, the Ringold Formation consists mainly of silt and fine sand strata that are characteristics of deposition in a current-carrying lake and its environs. The deposition apparently started when the Columbia River drainage was impounded in Middle Pleistocene time by the first uplift of the Horse Heaven Ridge (and downwarp of the Pasco syncline).

"Eastward and northward from the White Bluffs, the Ringold Formation lies at or near the plateau surface for many miles to where the basalt bedrock emerges at the surface. In the lowland swath between the east end of the Yakima Ridge and the White Bluffs, the ancestral Columbia River removed the Ringold strata down to a level below that of the present surface of the terraces. This eroded surface of the Ringold Formation has been covered by various thicknesses, up to about 200 feet, of glaciofluviatile and fluviatile deposits which underlie the land surface in most of the reservation area."

Recent stream alluvium and Pliocene glaciofluviatile deposits partly fill all the larger synclinal basins and stream valleys. These deposits, composed chiefly of unconsolidated silt, sand, and gravel, in places exceed 500 feet in thickness. The glaciofluviatile sediment has been described[55] as follows:

"The coarse clastic deposits that lie above the eroded top of the Ringold Formation and beneath the reservation terraces are somewhat similar to the coarsest materials of the Ringold Formation but in detail differ greatly. They have come to be known as glaciofluviatile and fluviatile deposits because they were water-laid by the ancestral Columbia River, in part while it was swollen by glacial melt water. Except for some material in the Touchet Beds, the glaciofluviatile and fluviatile deposits are largely current-laid deposits.

"The glaciofluviatile and fluviatile deposits consist of granule gravel, sand, and pebble gravel with some intermixed and interlayered silt as well as interbedded and included cobbles and boulders. These deposits mantle the eroded top of the Ringold Formation and some slopes of the basalt bedrock. They overlie the Ringold beneath the reservation, form the upper part of the northwestern end of the White Bluffs, and also underlie the terraces southward and eastward from the south end of the White Bluffs to and beyond Pasco. The greatest part of the deposits lie below an altitude of 800 feet, but the special facies, called the Touchet Beds, with its contemporaneous erratics, reaches to a common altitude of about 1,150 feet.

"Late in the glacial epoch, the facies of the glaciofluviatile and fluviatile deposits known as the Touchet Beds was laid down in a temporary lake (Proglacial Lake Lewis) created by the ponding of the Columbia River by a mountain glacier, ice jams, lava flows, or landslides, in the Columbia Gorge below The Dalles, Oregon. The Touchet Beds in its type occurrence consists of horizontally layered silt and sand. It includes scattered and clustered erratics that range from granules up to large blocks 6 to 8 feet in diameter. In the reservation area, the lake in which the Touchet Beds were laid down probably submerged a topography somewhat similar to that of the present time. The Touchet Beds accumulated as a lake-bottom deposit no more than 200 feet thick. The unit is best preserved in places that were the backwater or cove parts of the lake. On the reservation, the greatest amount of material occurs on the lower part of the Cold Creek Valley.

"The youngest of the glaciofluviatile and fluviatile deposits may be those deposits that now underlie the lowest terrace, such as the 400-foot terraces at old White Bluffs and Hanford and the 360-foot terrace at Richland. The demarcation between the last of the glaciofluviatile and fluviatile deposits and the first of the Holocene alluvium is obscure."

Recharge into the unconfined aquifer occurs from natural sources and from waste operations (synthetic recharge). The natural recharge on Gable Mountain moves through a very small local system on top of the synthetic system. The limit of the synthetic recharge defines the area in which the vertical component of hydraulic gradient, especially in the unsaturated zone, is directed downward.

Discharge over most of the discharge area is to the atmosphere via unsaturated flow to the surface and evapotranspiration. Generally this discharge is small to the point of being negligible but in Cold Creek Valley the native vegetation is visibly different and some phreatophytes are evident. The water supply for these plants may be supplied in part or in total by the discharging groundwater.

The area in which the water is moving through the surface part of the groundwater reservoir from the Yakima River to the Columbia River serves as a shallow local flow system which is underflowed by the synthetic flow system. The bulk of the liquid waste is discharged to five ponds in the 200 Areas: 1) Gable Mountain pond (216-A-25), 2) the 200 East Area (216-B-3, a pond east of the 200 East Area), 3) the 200 West Area (216-S-19, a pond south of the southeast corner of the 200 West Area), 4) the 200 West Area (216-T-4, a pond in the northwest corner of the 200 West Area), and 5) the 200 West Area (216-U-10, a pond in the southwest corner of the 200 West Area).

The impermeable boundaries of the unconfined aquifer are the Rattlesnake Hills, Yakima Ridge, and Umtanum Ridge on the west and southwest sides of the Hanford Reservation. Gable Mountain and Gable Butte also impede the groundwater flow. The Yakima River recharges the unconfined aquifer along its reach from Horn Rapids to Richland. The Columbia River forms a hydraulic potential boundary which is mainly a discharge boundary for the aquifer. However, the groundwater flow from 1 to 3 miles inland from the Columbia is affected by seasonable river stage fluctuations.[56-58] This river bank storage phenomenon has been reduced by increased control of the river flow by dams upstream of the Hanford Reservation. The volume of river bank storage under the Hanford Reservation has been estimated to be from 2×10^9 cubic feet to 3.6×10^9 cubic feet for a typical year.[56-59] Discharge of groundwater by evapotranspiration is considered negligible over the Hanford Reservation.

The major source of natural recharge is precipitation on Rattlesnake Hills, Yakima Ridge, and Umtanum Ridge which outcrop to the south and west of the Reservation. The water percolates underground near the base of the highlands and moves into the Reservation area.[54] Flow from springs emerging on the flanks of these hills and ridges generally sinks into the ground within a mile of the sources.

The average flow of Cold Creek and other infiltration water in that section has been estimated at 72,000 cubic feet per day, of which perhaps half reaches the water table.[55] Estimated recharge from the Dry Creek and Rattlesnake Springs area average about 36,000 cubic feet per day over the year. Additional recharge may be caused by leakage upward from the underlying confined aquifers along the western boundary of the Reservation. Recent irrigation developments in the Cold Creek Valley could substantially augment the natural recharge from this area.

The natural recharge due to precipitation over the lowlands of the Hanford Reservation is not measurable. A minor amount occurs where the water table is close to the land surface.[55] The Hanford Reservation is in the rain shadow of the Cascade Mountains with average annual precipitation of 6.3 inches (the higher ridges receive about 12 inches per year). A maximum 24-hour precipitation of 1.91 inches and a maximum monthly precipitation of 3.08 inches have been recorded since 1912.[36] The primary return of rainfall to the atmosphere takes place almost immediately, before deep penetration can occur. Drying of the land surface by wind and low humidity air produces a gradient of water potential toward the surface. The evaporation potential during the summer months greatly exceeds total precipitation. Data on migration from natural precipitation in deep soils (below 30 feet) show movement rates of less than 1/2 inch per year at the one measurement site available.[61-63]

The points of significant withdrawals of water on site at the present time are at the FFTF site (400 Area) and at the Washington Nuclear Plant No. 2 reactor site under construction. These are temporary withdrawal points of large groundwater flows that affect only the local groundwater flow patterns.

II.3-D.4.2 <u>Water Table</u>

The water table is that surface in an unconfined groundwater body at which the pressure of the water is atmospheric. The water table is defined by the levels at which water stands in wells that penetrate the saturated soil just far enough to hold standing water. In wells penetrating to greater depths, the water level may stand above or below the water table if an upward or downward component of groundwater flow exists. Only data from wells which have been analyzed and determined to provide data representative of the water table are used in developing water table maps for the Hanford Reservation.

The present elevation of the unconfined groundwater aquifer can be visualized by looking at the contour map of the water table. The map for January 1975 is shown in Figure II.3-D-12. The wells used in determining the water table are also shown. The accuracy of the contouring is directly related to the density of the measurement points, the local gradients and the accuracy of measuring water levels and well elevations.

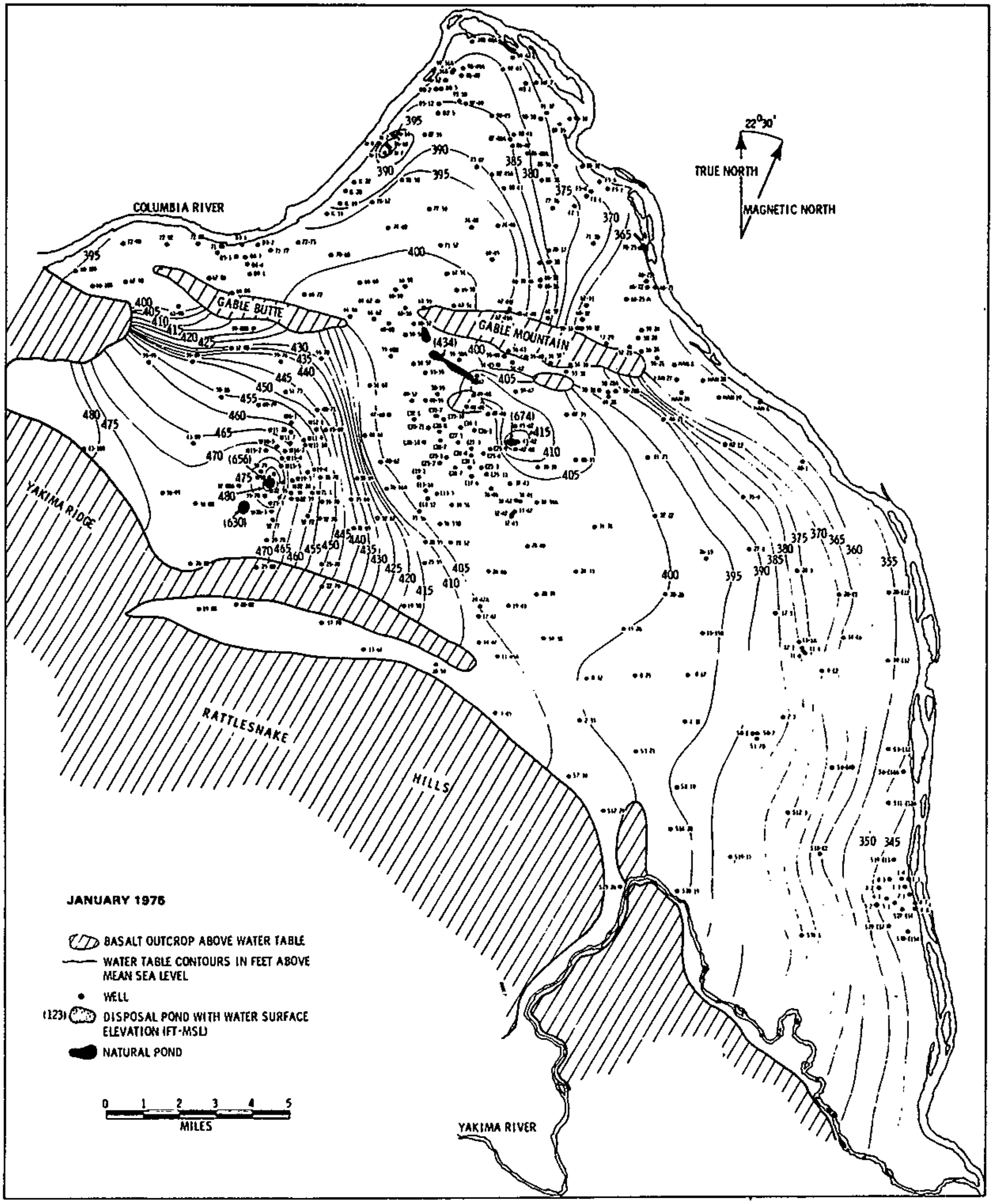


FIGURE II.3-D-12 HANFORD RESERVATION WATER TABLE MAP

A geologic cross section, Figure II.3-D-13, shows the water table elevations at three times during the history of the Reservation (a vertical to horizontal distortion is noticeable). The depth to the water table varies greatly from place to place, depending chiefly on local topography, and ranges from less than 1 to more than 300 feet below the land surface. Beneath most of the 200 Area disposal sites the depth to water averages about 250 feet. The current estimate of the maximum saturated thickness of the unconfined aquifer is about 230 feet.[64]

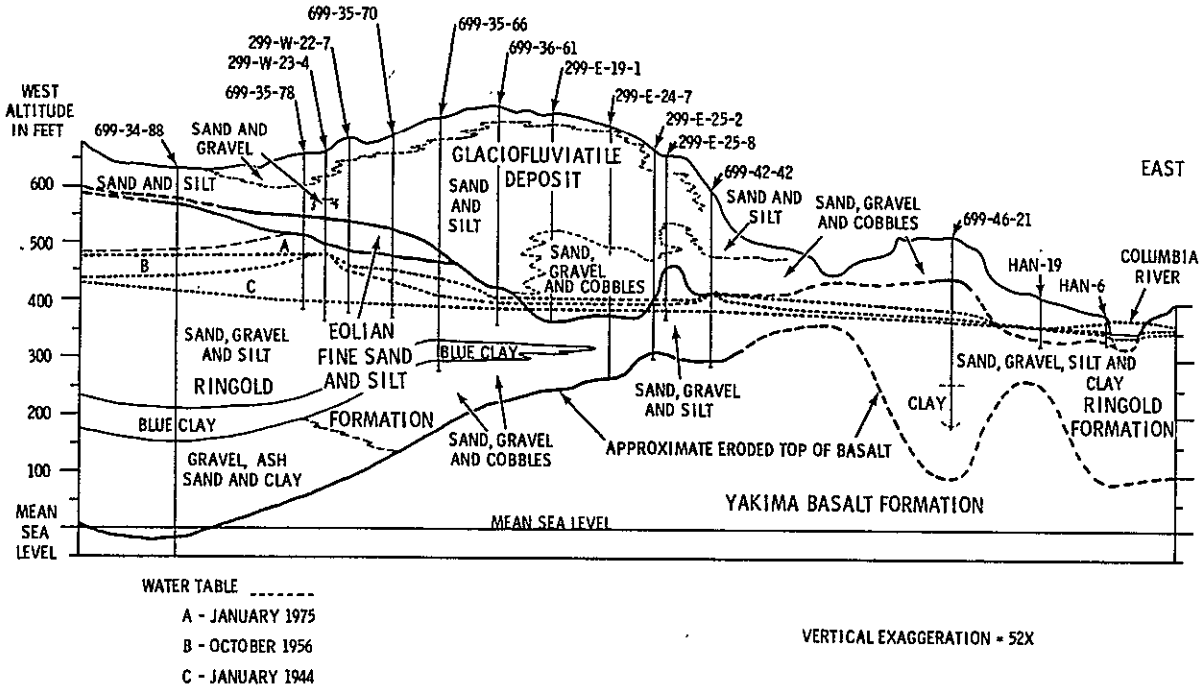


FIGURE II.3-D-13 GEOLOGIC CROSS SECTION - HANFORD RESERVATION

From 1944 through 1973 (the last year for which data have been compiled), the chemical processing plants have discharged to ground over 132 billion gallons (4 x 10^5 acre feet) of waste water and cooling water. Such a large volume of water has had an effect on the regional water table. Figure II.3-D-14 shows the water table map (a hindcast made in 1955) before Hanford operations, as interpreted from the earliest water level measurements. Water table maps have been prepared over the years; a representative selection of water table maps for the 30 years of Hanford operation is available.[65]

Two distinct groundwater mounds have been created from the large volume of process water disposal on the 200 Area plateau. Their locations, elevations, and shapes at any given time have been functions of the recharge rates, both previous and current, and the local aquifer characteristics. The present pattern of groundwater movement is affected by the topography of the water table and the saddle or groundwater divide that lies to the north of 200 East Area. The peak of the western mound is about 480 feet above MSL, which represents a rise of about 85 feet from preoperation conditions. The eastern mound peak is about 418 feet MSL representing about a 28-foot rise. Historical well hydrographs (Figure II.3-D-15) show the development and fluctuation of these mounds with time at monitoring wells. Rising groundwater levels have been measured as far as 16 miles away from the recharge site (Figure II.3-D-15c).

The unconfined aquifer under the Hanford Reservation has a maximum thickness of 230 feet and extends approximately 30 miles north-south and 25 miles east-west at its maximum dimensions. Therefore, this system has a horizontal-to-vertical ratio of from 570:1 to 690:1. The maximum range in potential within this system is from 480 feet to 340 feet elevation. Primarily horizontal flow within this system has been observed except in the immediate vicinity of recharge areas. Variation of hydraulic potential with depth within the unconfined aquifer has been determined to be negligible except in areas close to recharge sites. The hydraulic conductivity over the Reservation has been observed to vary from 1 to 1 x 10^4 feet/day and is assumed to be isotropic within the unconfined aquifer at any specific location.

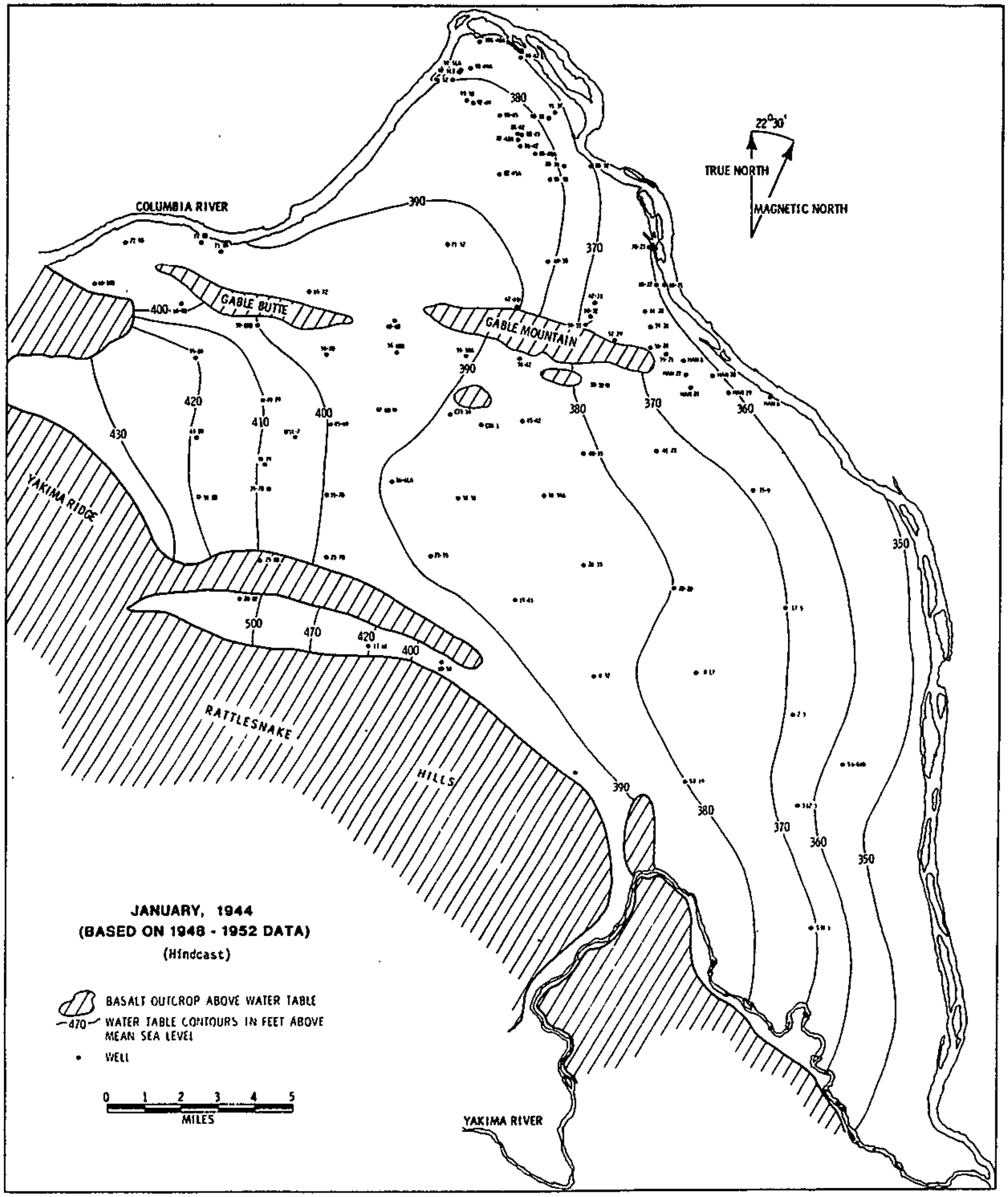


FIGURE II.3-D-14 HANFORD RESERVATION WATER TABLE MAP
January, 1944, Hindcast

This reasoning leads to the deduction that the groundwater velocity vector is perpendicular to the water table contour lines and points in the direction of lower hydraulic potential (water table elevation). Therefore, for any groundwater potential map (water table map) in an unconfined system, flow paths can be drawn illustrating the direction of groundwater movement at that specific time. A parcel of water will follow one of these streamlines only as long as the

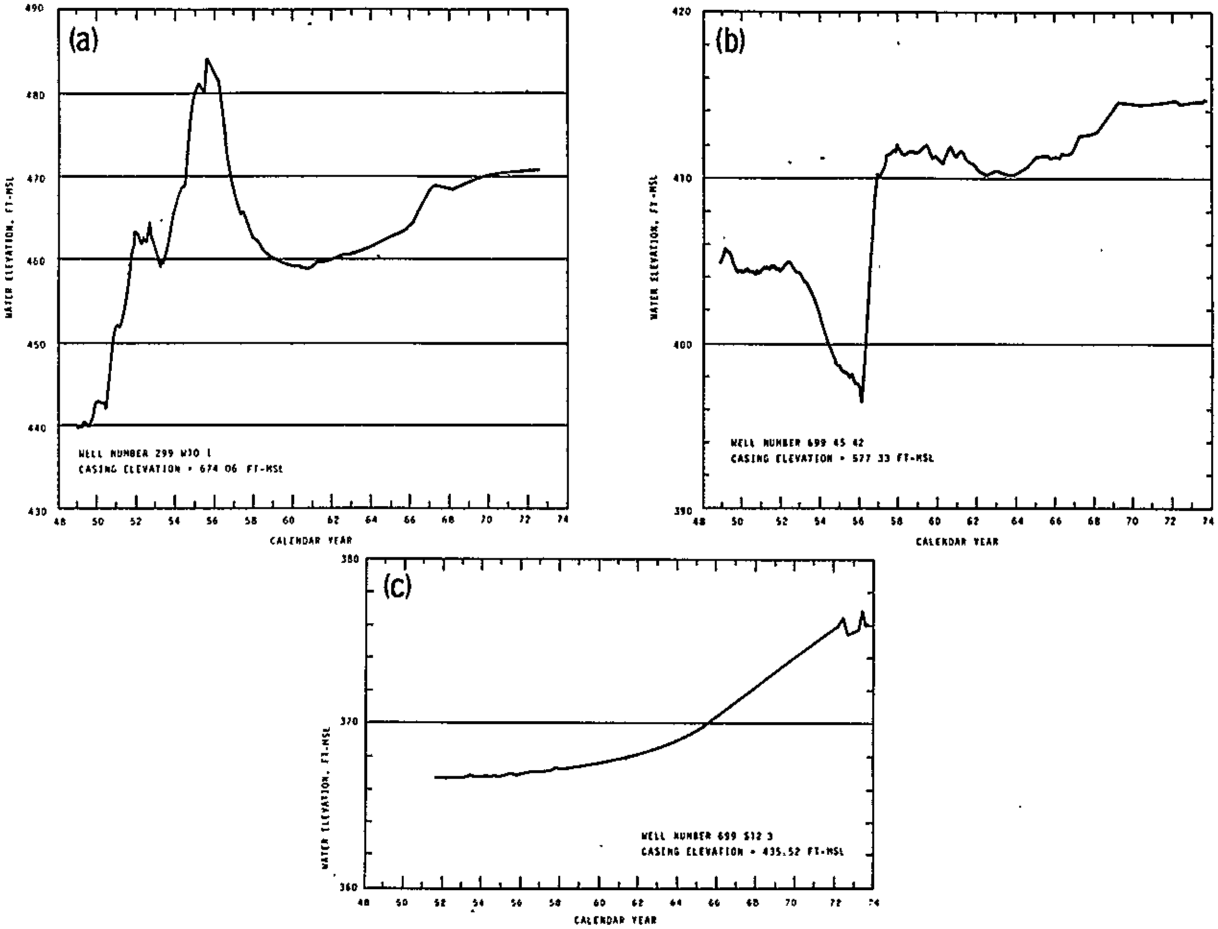


FIGURE II.3-D-15 WELL HYDROGRAPHS

potential contours remain the same. A slowly changing water table configuration will cause that parcel of water to follow the slowly changing instantaneous streamline. Its resulting path from one point to another is called a pathline. A pathline of a fluid particle is the locus of its positions in space as time passes. Thus, it is the path of a particle of fixed identity.

The groundwater potential contours over most of the Reservation change slowly enough that the instantaneous streamlines probably do not move significantly over a period of a few years. However, within 1 to 5 miles of the Columbia River the annual recharge and discharge of river bank storage occurs with a daily fluctuation in the immediate vicinity of the river's edge, thus producing transient streamlines in this area. The other area of seasonal contour adjustment is the 200 East Area, where the groundwater saddle or divide is affected by the river bank storage phenomenon and periodic adjustments in recharge flow rates. The relative flatness of the water table in this area (a result of the rather high hydraulic conductivities of these sediments) makes it sensitive to changes in boundary and recharge conditions. Figure II.3-D-16 shows the January 1972 water table map with some instantaneous streamlines starting at discharge ponds.

Instantaneous streamlines are useful as indicators of direction of movement and represent the path a particle of water would take if and only if it were in a steady-state flow system. A pathline, the true path of a particle in a transient system, can only be defined if a tagged particle could be followed. Definition of pathlines is needed but difficult since pathlines are normally defined only in closed-form mathematical solutions. Discrete surfaces (water tables) are not easily adapted to pathline definition, but through the use of models that permit development of closely spaced, consistent surfaces a pathline can be approximated.

The previously mentioned groundwater saddle or divide under the 200 East Area makes both northward and southeastward transport from the 200 East and 200 West processing areas possible.

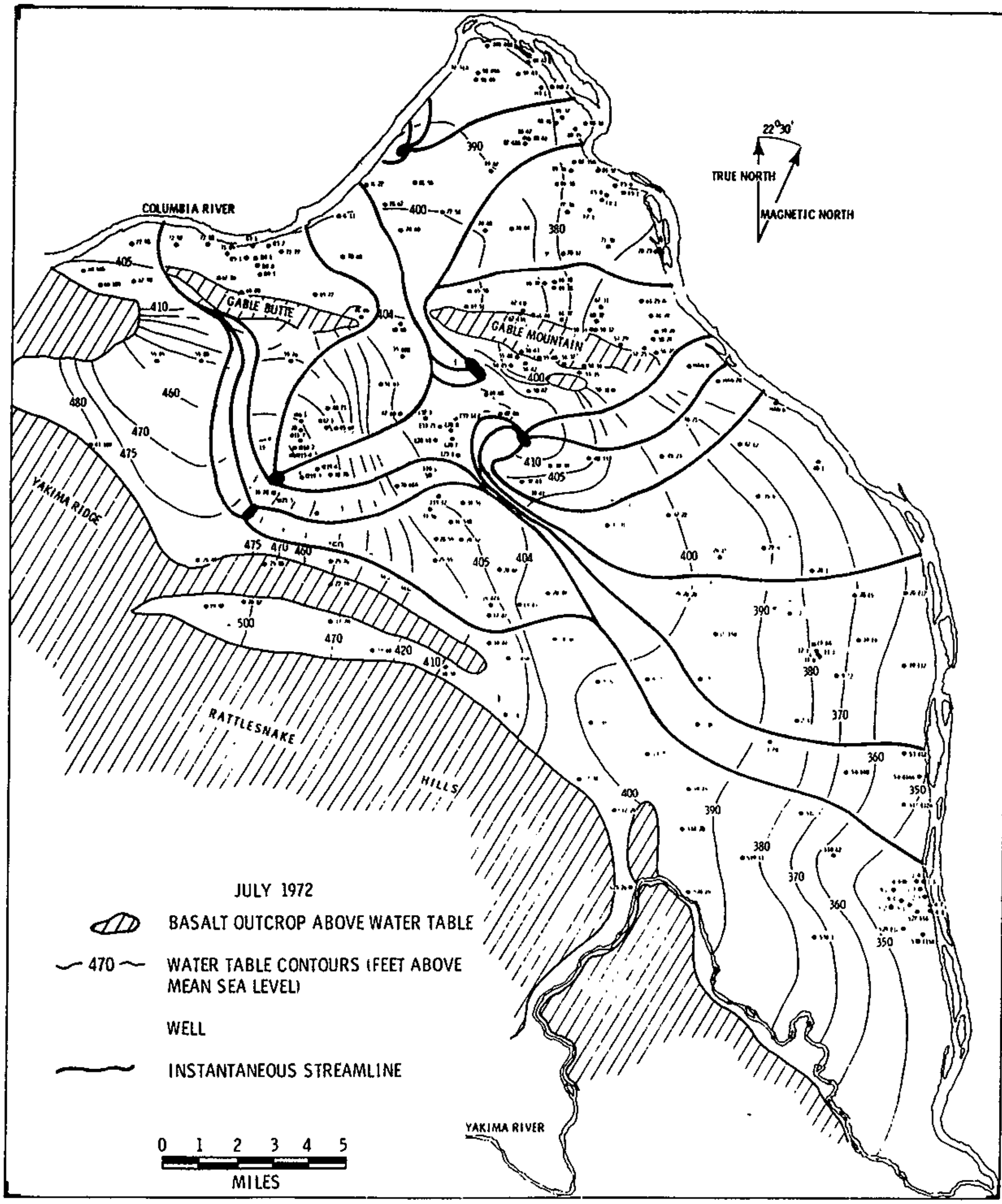


FIGURE II.3-D-16 1972 WATER TABLE MAP WITH STREAMLINES

Radioactive contaminants, upon reaching the water table, are convected in the direction of groundwater movement. Thus, the infiltration site is of critical importance in evaluating the fate of any radioactive waste that enters the groundwater. Ultimately, all groundwater in the unconfined aquifer beneath the 200 Area plateau, except that which is lost to the atmosphere by evapotranspiration or by evaporation from West Lake, enters into the Columbia River.

In the past, small groundwater mounds were formed under each of the reactor areas by leakage from the cooling system water lines and holding basins. Each of these mounds subsided within several months after shutdown of the nearby reactor. Only the small mound at 100-N Area remains (Figure II.3-D-16), the result of discharges to the 1301-N crib. A similar groundwater mound was created and continues at the 300 Area infiltration site from the process waste ponds and sanitary leach trenches.

West Lake, located near the western end of Gable Mountain, is a naturally occurring lake whose surface is continuous with the phreatic surface of the groundwater. In a small area north of Gable Mountain, a small perched water lens (identified in three shallow wells) is apparently the remanent leakage from the old Hanford irrigation system ditch that conducted water through this area. A local clay deposit appears responsible for this occurrence.

The velocity of groundwater flow through the aquifer is of major significance in evaluating the potential impact of groundwater discharges.

II.3-D.4.3 <u>Field Programs</u>

The hydraulic characteristics of importance for the unconfined aquifer are the hydraulic conductivity, the storage coefficient, the aquifer thickness, and the effective porosity. The hydraulic conductivity relates the quantity of groundwater flow to the gradient of the hydraulic potential, while the effective porosity gives the fraction of porous media volume that is available to transmit groundwater flow. The storage coefficient relates a change in the water table elevation to a change in the volume of water contained in the aquifer per unit of horizontal area. In the limit, the storage coefficient is equal to the effective porosity of the soil through which the water table moves. These parameters are functions of location in the aquifer and have highly heterogeneous distributions over the Hanford Reservation.

In its most general form the hydraulic conductivity is a tensor accounting for anisotropic flow conditions. Under the assumption of isotropic flow this quantity reduces to a scalar. No studies to evaluate possible anistropic flow conditions have been made on the Hanford Reservation. However, comparison of observed contamination plume movement with the direction of groundwater gradients indicates that anisotropy is not a significant flow parameter in the horizontal plane.

Qualitatively the hydraulic conductivity, storage coefficient and effective porosity distributions are functions of the different geologic formations in the unconfined aquifer. The Ringold Formation is frequently divided into a lower clay zone, a middle conglomerate zone, and an upper silty zone, although marked lithologic changes occur both horizontally and vertically within these zones, precluding a precise definition. Incised in the Ringold Formation are ancestral Columbia River channels filled with more permeable glaciofluviatile sediments. Channels of highly permeable sediments have been identified extending eastward along the northern and southern flanks of Gable Mountain and southeastward from the 200 East Area to the Columbia River.[66]

A geophysical study to analyze the distribution of permeable ancestral channels was initiated in 1974. This investigation (not yet completed) included a regional gravity survey over the entire area of the Hanford Reservation. A map is presently being prepared showing the probable ancestral course of the Columbia at various periods of time. Residual gravity anomalies are presently being evaluated and their geohydrologic importance analyzed. These anomalies are probably the result of folding of the basalt, erosion of folds during folding, and filling of the synclinal troughs with the Ringold Formation and glaciofluviatile materials.

Quantitative measurements of the hydraulic conductivity have been made at locations over the Hanford Reservation using a variety of techniques.[66,67] With these techniques, an average hydraulic conductivity over the saturated thickness of the unconfined aquifer was determined at each test site. Field tests have included pump tests, specific capacity tests, tracer tests, cyclic fluctuations of the water level, and regional hydraulic gradient integrations. Excluding the clay zone, the values obtained for the Ringold Formation ranged between the moderate values of 1 to 200 feet per day. In sharp contrast are the very large hydraulic conductivities of glaciofluviatile sediments--ranging from 1,200 to 12,000 feet per day. Higher values from specific capacity test data should be regarded with caution due to the inherently low accuracy of this type of test. The glaciofluviatile sediments in general are about 100 times more permeable than the Ringold Formation. A summary of test results is given in Table II.3-D-13.[66-68]

A study[69] of the areal distribution of transmissivity and hydraulic conductivity was recently completed which used pumping tests conducted by others at Hanford during the past 20 years.[66-68] Most of the tests were run without observation wells thus precluding an accurate determination of storage coefficient. Those tests conducted with observation wells were generally too short to accurately obtain a value for delayed yield. Pump fluctuations precluded the use of drawdown data for many of the tests. Results of the interpretation of these tests are shown in Table II.3-D-14. With the exception of the last two results, all values represent the characteristics of the upper zone of the unconfined aquifer (most of the wells tested only partially penetrate the aquifer).

TABLE II.3-D-13

AVERAGE FIELD HYDRAULIC CONDUCTIVITY (FT/DAY) MEASUREMENTS

Tested	Pumping Tests	Specific Capacity Tests	Tracer Tests	Cyclid Fluctuations	Gradient Method
Glaciofluviatile	1,200-12,000	1,300-17,000	8,000	2,200-7,600	-
Glaciofluviatile and Ringold	120-670	130-530	-	130-800	-
Ringold (including clays)	1-200	8-40	-	20-60	13-40

TABLE II.3-D-14

PUMPING TEST DATA RESULTS FOR THE UNCONFINED AQUIFER

	Well No.	Transmissivity (ft^2/day)	Hydraulic Conductivity (ft/day)	Thickness (ft)	Depth to Water (ft)	Summary of Results[69]
A.	699-77-54	7,000	97	72	78	North of the Gable Butte area the transmissivity is highest close to the river.
	199-K-10	22,500	260	86	78	
	199-K-12	21,600	250	86	78	
	699-87-55	4,500	130	35	65	
B.	699-61-66	>40,000	>400	104	116	Very high transmissivities on the flanks of Gable Butte and Gable Mountain.
	699-63-90	296,000	2,300	127	113	
	699-55-50	594,000	9,100	65	40	
C.	699-26-15	9,500	200	48	54	Transmissivity ranges from 1,000-40,000 ft^2/day; highest in Cold Creek Valley south of the Cold Creek syncline.
	699-36-61	2,800	43	65	339	
	699-33-56	22,000	250	88	317	
	699-31-53	21,000	165	127	303	
	699-17-47	5,300	50	105	174	
	699-8-17	35,000	640	55	135	
	699-47-60	3,300	80	41	243	
	699-35-9	2,250	45	50	114	
D.	699-26-89	525	2	229	175	Multiple aquifer averages include clay layers.
	699-S12-3	350	9	40	68	

A study is presently being conducted to evaluate the hydraulic conductivity distribution in the unconfined aquifer over the Hanford Reservation using driller's logs.[70] Results indicate good agreement with pumping test data. An extensive pumping test program is presently underway to extensively characterize the hydraulic characteristics of the Reservation. To date all existing data have been evaluated and processed using the Transmissivity Iterative Routine (TIR) Model (discussed in the next section) to obtain the most accurate map of the hydraulic conductivity distribution of the Hanford unconfined aquifer. This map is shown in Figure II.3-D-17.

The effective porosity and storage coefficient are much more difficult to measure in the field. A properly designed pumping test can yield a value for the storage coefficient, but some type of tracer test or well logging procedure is necessary to obtain values of effective porosity over the saturated aquifer thickness. Values for the storage coefficient parameter ranging from 0.0008 to 0.2 have been estimated for the Hanford area from field tests but the quality of these values is poor. A typical range of storage coefficient values for unconsolidated sediments is 0.05 to 0.4. For the purposes of groundwater flow and radionuclide transport simulation modeling, the effective porosity over the saturated thickness of the aquifer is assumed to be initially equal to the storage coefficient.

II.3-D.4.4 Groundwater Models [X.24]

Attempts to develop a practical tool for managing the groundwater basin led to development of simulation techniques. Initially, simple graphical flow net analyses and analog models were applied and evaluated. In the early 1960's a program was initiated to develop the capability to predict transport of contaminants in Hanford sediments. Early models developed to predict groundwater movement under steady state conditions required many compromising assumptions to simulate the system. The models were not able to simulate transient conditions or waste transport and thus were not effective tools for managing a groundwater basin.

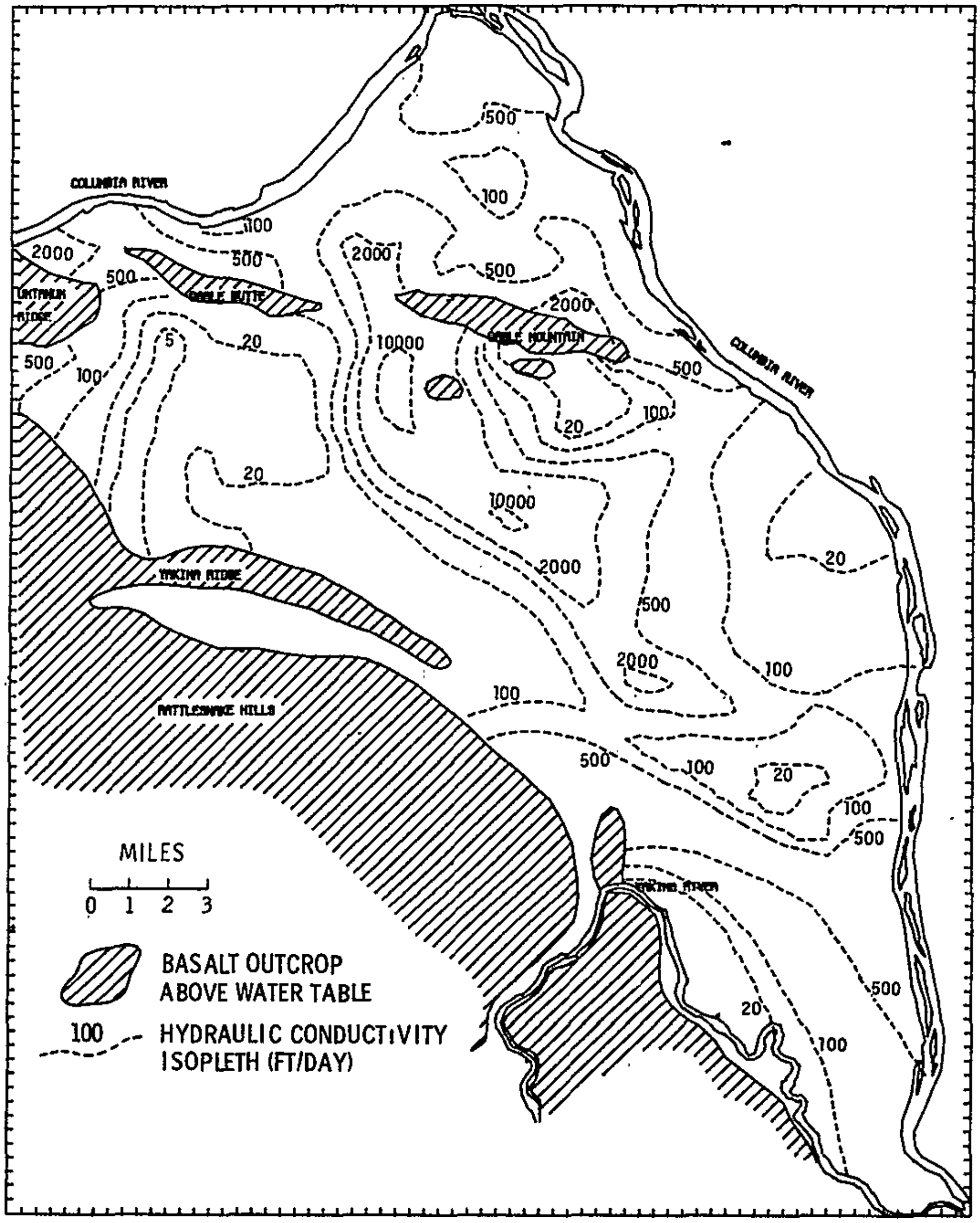


FIGURE II.3-D-17 HYDRAULIC CONDUCTIVITY DISTRIBUTION OF THE HANFORD UNCONFINED AQUIFER

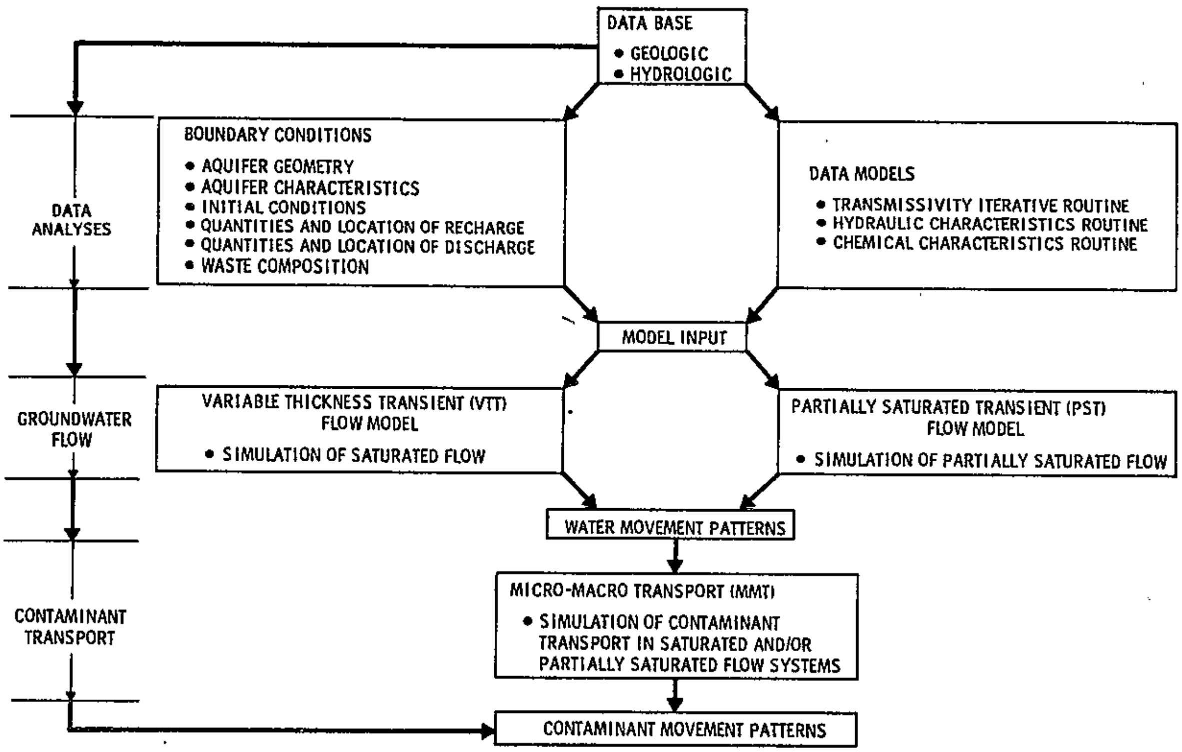
In the late 1960's an intensive effort was initiated to develop a more refined model that would provide transient analysis of contaminant movement. Development of the present system of models was based on the economics of data input requirements, accuracy of results and practicality of application. In addition to the models, a man-machine interactive computer system was developed to provide an efficient means for utilizing the models and analyzing the results. The program goal was to produce a management and engineering tool for use in analyses, decisions, and policy formulations relative to management of groundwater systems. To date, models for describing groundwater and contaminant movement in the unsaturated zone and the unconfined aquifer have been developed and tested against analytical solutions and limited field data. The testing provided confidence in the mathematical methods and the approach being used. Verification with field data showed areas where data coverage was inadequate and pointed up the need for development of a technique to compute uncertainties in the output based on known uncertainties in the input data. Additional data and work are needed to reduce the uncertainty in the model predictions.

In general, the Hanford Reservation modeling is divided into three categories: 1) unsaturated zone analysis capability, 2) saturated unconfined groundwater analysis capability, and 3) transport capability. The unsaturated and saturated portions of the groundwater system were considered separately in order to develop feasible models. The transport phenomena were assumed to be affected by, but not to affect, the convective flow patterns.

The model development effort is separated into three major categories: data models, hydraulic models, and contaminant transport models. Data models calculate from a relatively small number of field measurements the input characteristics required for operation of the hydraulic and transport models. The hydraulic models predict the groundwater velocities in the unsaturated and saturated sediments. The transport model combines the groundwater movement calculated by the hydraulic models with soil-waste reactions to predict the contaminant movement rate. The groundwater convective transport is simulated independent of waste movement. Table II.3-D-15 lists the models and their respective functions as well as input data requirements and output information. (All of these models are in the development stage and are presently undergoing review and revisions.)

TABLE II.3-D-15

HYDROLOGIC MODELS



A major data model, the TIR, has been developed for calculating the hydraulic conductivity distribution in highly heterogeneous aquifers where characterization by field measurement alone would be prohibitive. The method is based on the numerical integration of the Boussinesq equation for the transmissivity along instantaneous streamtubes of flow. Testing of the computer program on a synthetic surface identified a set of control parameters that resulted in a maximum computation error of ±5%. This maximum error occurred as streamtubes passed near stagnation points where the groundwater gradients and radius of curvature were small. Two versions of the program, steady and transient, were implemented on the Hanford unconfined aquifer. Although the earlier steady version was a limited program, the verification by comparison of computed and observed groundwater potentials assuming steady conditions, while far from perfect, was encouraging, and the resultant distribution represented a substantial improvement over the previous version.[71]

The results of limited sensitivity analysis on the Hanford unconfined aquifer indicated that, in general, the flow in the aquifer is sufficiently greater than the rate of storage to make the calculation of the hydraulic conductivity relatively insensitive to the storage coefficient. A good average estimate is that a 100% error in either storage coefficient or temporal rate of change will result in a 20% error in the calculated hydraulic conductivity measurement because of the extreme sensitivity of the calculated hydraulic conductivity generated for certain streamtubes. The agreement of calculated hydraulic conductivities of the reference lines and analysis of pump test data support these observations. Details of the model assumptions, limitations, error and sensitivity analyses are contained in a recent report.[71]

The basic hydraulic models are the Variable Thickness Transient Groundwater Model (VTT) and the Partially-Saturated Transient Flow Model (PST). The VTT Model was developed to predict the changing height of the water table (phreatic surface) throughout the unconfined aquifer underlying the Hanford Reservation. It provides for the simulation of two-dimensional flow in unconfined aquifers. The model utilizes the nonlinear transient Boussinesq equation with the appropriate initial and boundary conditions. The heterogeneous permeability distribution input can be calculated by the TIR. A successive line over-relaxation technique with unequal time steps is used for numerical solution.

The PST Model includes a mathematical description and computer program to simulate transient Darcian transport of a fluid in heterogeneous partially-saturated porous media.[50] The objective of the model is to assess movement of groundwater in the unsaturated zone. The model involves the solution of the basic two-dimensional equation of flow in the unsaturated region.[50]

A transport model[72,73] has been developed for use with the PST and VTT Models for predicting movement and distribution of contaminants in groundwater systems. Based on the two-dimensional form of the general diffusion-convection equation, the model considers variable dispersion coefficients, variable media thickness and sink and/or source terms. The model has two major components: the macroion segment handles dissolved minerals that are typically present in groundwater systems, and the microion segment predicts movement of contaminants which are normally present in trace quantities (in comparison to the naturally-occurring materials). The model encompasses the compound problem of multicomponent transport with simultaneous chemical reactions and includes the general transport mechanisms of advection, dispersion, and sorption, as well as radioactive decay. Each segment can be run as a separate model.

II.3-D.4.5 Groundwater Monitoring Program [X.18, X.24]

The groundwater monitoring program provides information on the movement of contaminants in the groundwater beneath the Reservation which aids in evaluating the impact of liquid waste disposal to the environment and assures compliance with AEC Manual Chapter 0524 standards[76] for release of radioactive waste to uncontrolled areas. EPA drinking water standards[86] are used to evaluate nonradioactive contaminants in the groundwater.

Groundwater data summaries and evaluations including maps are reported in the series "Radiological status of the Groundwater Beneath the Hanford Reservation for . . ."; the latest issue is BNWL-1860 for 1973.[87] Results from offsite water supply wells are reported in the annual "Environmental Surveillance at Hanford for . . ."; the latest issue is BNWL-1910 for 1974.[88] A complementary groundwater monitoring program is carried on within the 200 Areas to provide data to support the management of the liquid waste disposal-to-ground operations at cribs, trenches and ponds. Data from this program are also used in the general environmental groundwater evaluations.

The groundwater is sampled from about 310 wells routinely. The sampling frequency varies from monthly to semi-annually, depending on the location of the well and the constituents being followed. Tables II.3-D-16 through 19 show July - December 1973 average values for gross beta, tritium and nitrate as well as the sampling frequency for each constituent. Current frequencies may differ somewhat due to revisions in the sampling schedule. Maps illustrating these data appear in Figures II.3-D-18, -19, and -20. Most of the samples are dipped from the surface of the water in the well and are assumed to be representative of conditions near the surface of the unconfined aquifer. At a few locations where well structures are available, samples from the lower confined aquifer zones are obtained by air lift pumping from piezometer tubes. Conversion to permanently installed submersible sampling pumps for key wells is in progress.

TABLE II.3-D-16

AVERAGE GROSS BETA, TRITIUM, AND NITRATE ION CONCENTRATIONS IN 600 AREA WELLS ASSOCIATED WITH THE 200 AREAS (UNCONFINED AQUIFER)

	Gross Beta[a] (pCi/ml)		Tritium (pCi/ml)		Nitrate (mg/l)	
Analytical Limit	0.08		1.0		0.5	
Concentration Guide	(b)		3000		45	
Well Number	Sampling Frequency	July-Dec 1973	Sampling Frequency	July-Dec 1973	Sampling Frequency	July-Dec 1973
699-S0-8			Q	37	SA	7.3
699-S3-E12			SA	(c)	BM	7.5
S3-25			Q	(c)	Q	(c)
S6-E4-D			Q	(c)	BM	2.8
S8-19			Q	(c)	Q	1.0
S12-3			Q	(c)	Q	0.8
S12-29-0					SA	(c)
S19-11					SA	(c)
1-18			SA	190	BM	3.8
2-3			Q	44	BM	7.8
2-33-0			Q	(c)	SA	(c)
3-45					SA	(c)
8-17	Q	(c)	SA	140	SA	23
8-25	Q	(c)	Q	235		
8-32			Q	(c)	BM	0.5
9-E2		0.20	Q	(c)	Q	(c)
10-E12-0					BM	11
11-1		(c)	Q	27	Q	1
13-1A		0.15	Q	129	Q	8.9
13-1B		(c)	Q	54	Q	6.6
15-15-B	Q	(c)	Q	(c)	Q	10
15-26	Q	(c)	SA	400	SA	28
17-5		(c)	BM	1.4	BM	5
19-43					Q	3.3
699-20-E12-0					SA	(c)
20-20	Q	0.12	SA		SA	
20-39-0			Q	(c)	Q	1.3
24-33	Q	(c)	SA	430	Q	5.8
25-70-0					Q	3.3
26-15	Q	0.24	SA	1300	SA	53
26-89					SA	
27-8	Q	(c)	SA	1000	Q	12
28-40-0	Q	(c)	SA	40	Q	8.8
29-78			Q	(c)	Q	2.9
31-53B-0	SA	(c)	Q	(c)	Q	8.0
31-65-0			Q	1.1	Q	14
32-22	Q	0.30	SA	1500	Q	61
32-43	SA	0.18	SA	700	SA	33
32-62-0			Q	8.1	Q	(c)
32-70	Q	(c)	Q	49	SA	18
32-72-0	Q	(c)	SA	75	BM	(c)
32-77	Q	(c)	Q	(c)	Q	9.8
33-56	SA	(c)	Q	(c)	Q	(c)
34-39A	Q	(c)	SA	1800	Q	5.6
34-41	Q	0.23	Q	2000	Q	68
34-42	Q	0.35	Q	1930	Q	74
34-51	Q	(c)	Q	(c)	BM	1.1
35-9	Q	(c)	Q	45	BM	6.7
35-66	SA	(c)	Q	2.8	Q	(c)
699-35-70	Q	0.10	Q	8100	Q	2.8
35-78	Q	(c)	Q	1.7	BM	1.2
36-61-A	SA		Q	(c)	Q	9.5
37-43-0	Q	(c)	Q	93	Q	(c)
37-82A-0			Q	(c)	Q	18
38-70-0	Q	0.23	Q	81	Q	154
39-39	Q	(c)	Q	(c)	Q	(c)
39-79-0	Q	(c)	Q	1.1	BM	1.1
40-1			Q	(c)	Q	(c)
40-33	BM	(c)	Q	1.3	Q	(c)
40-62			Q	1.4	Q	16
41-23	Q	0.08	SA	845	Q	51
42-12	Q	0.13	SA	260	BM	30
42-42-0			SA	49	Q	7.5
43-42	BM	(c)	Q	290	Q	(c)
43-89			SA	(c)	Q	28
44-64-0			Q	(c)	Q	14
45-42			SA	820	Q	0.6
45-69			Q	(c)	Q	40
46-21	Q	(c)	Q	(c)	BM	5.1
47-35			Q	(c)	Q	1.3
47-46			Q	(c)	Q	18
47-60			Q	(c)	Q	8.8
48-71			Q	(c)	Q	1.6
49-28			SA	(c)	Q	(c)
49-55	Q	(c)	Q	(c)	Q	(c)
49-57	Q	1.6	Q	115	Q	127
49-79			SA	(c)	Q	15
50-28A			Q	(c)	BM	4.3
50-30					Q	(c)
50-42-0			Q	3.8	Q	(c)
50-53	Q	0.58	Q	1.7	Q	84
50-85			SA	(c)	Q	11
51-63			Q	(c)	Q	1.6
51-75-0			Q	1.5	Q	11
53-47			Q	2.3	BM	(c)
53-55-0			Q	1.1	Q	(c)
54-42			SA	(c)	Q	3.7
54-45			Q	(c)		
54-57			Q	(c)	Q	(c)
55-50A			Q	1.1	BM	0.6
55-70-0					Q	0.9
55-76-0					Q	0.9
57-83-0					Q	(c)
59-58			Q	4.0	Q	(c)
59-80B					Q	37
HAN-6			Q	(c)	BM	3.6
HAN-9					BM	3.4
HAN-19			Q	(c)	Q	2.8

(a) Gross Beta is calculated as ^{106}Ru.
(b) The ^{106}Ru Concentration Guide is not strictly applicable to an unknown mixture of beta emitters.
(c) Indicates that the concentration was less than the analytical limit.
No entry indicates no analyses were performed during the 6-month period.
Sampling Frequency Code: SA - Semiannual; Q - Quarterly; BM - Bimonthly; M - Monthly.

TABLE II.3-D-17

AVERAGE GROSS BETA, ^{60}Co, NITRATE, AND ^{106}Ru CONCENTRATIONS IN THE UNCONFINED GROUNDWATER WITHIN THE 200 AREAS

	Gross Beta[a] (pCi/ml)		Tritium (pCi/ml)		Nitrate (mg/l)	
Analytical Limit	0.08		1.0		0.5	
Concentration Guide	(b)		3000		45	
Well Number	Sampling Frequency	July-Dec 1973	Sampling Frequency	July-Dec 1973	Sampling Frequency	July-Dec 1973
299-E13-3	SA	(c)				
E16-2	M	0.6			Q	5.2
E17-1	BM	0.11	BM	6000	BM	147
E17-2	BM	0.13				
E17-4	BM	0.59				
E17-5	BM	0.27			BM	282
E17-6	M	0.09				
E17-7	M	1.3			BM	385
E17-8	BM	0.14			BM	193
E17-9	BM	0.29				
E17-10	BM	0.27				
E19-1	SA	(c)				
E23-1					SA	24
E24-2	M	0.18			Q	422
E24-4	BM	(c)	SA	810	SA	25
E24-7					SA	31
E24-9	BM	0.20			BM	198
E24-10	BM	0.09	Q	17500	BM	1.0
E24-11	BM	0.10				
E24-12	BM	0.24			M	206
E24-13	M	(c)				
E24-14	M	(c)				
E25-1	M	0.09				
E25-2	M	(c)				
E25-5	M	0.10				
E25-6	M	(c)	M	965	Q	30
E25-9	M	(c)				
E25-10	BM	0.13				
E25-11	BM	1.4				
E25-12	M	1.5				
E25-13	M	(c)				
E25-16	M	0.09				
E26-1	Q	(c)				
E26-4	M	0.14			Q	5.5
E26-5	BM	0.12				
E27-1					Q	11
E28-8	BM	0.10				
E28-9	BM	0.20	BM	106	BM	233
E28-12	M	0.11	BM	24		
E28-13	BM	(c)			Q	43
E28-16					Q	227
E28-17	BM	0.12				
E28-18	M	4.3				
E28-19	BM	9.9				
E28-20	M	5.2				
E32-1	SA	0.25				
E33-7	M	5.4				
E33-9	M	0.94				
E33-18	BM	0.30				
E33-23	M	0.34	BM	1400	M	28
E33-24	M	1.9				
E33-25	BM	1.6	BM	108	BM	439
299-E33-26	BM	1.6				
E34-1					Q	(c)
W6-1	SA	(c)			Q	530
W10-1	BM	(c)		(c)		
W10-2	BM	0.09	BM	6.3	BM	2082
W10-3	BM	(c)				
W10-4	BM	0.10				
W10-8	M	(c)			SA	25
W11-3	SA	(c)			Q	96
W11-15	BM	0.31				
W11-17	BM	(c)			Q	158
W11-18	BM	(c)				
W11-20	M	(c)	M	196	M	90
W14-1	BM	0.19				
W14-2	BM	1.6			BM	498
W15-1	BM	(c)				
W15-4	M	0.10	M	3580	M	382
W15-5	BM	(c)				
W15-6	BM	(c)				
W15-7	BM	0.68			Q	110
W15-8	BM	(c)				
W15-9	BM	0.08				
W15-10	BM	(c)				
W15-11	BM	(c)				
W18-1	M	(c)				
W18-2	BM	(c)				
W18-3	BM	(c)				
W18-4	BM	(c)				
W18-5	BM	(c)	SA	93	SA	(c)
W18-7	BM	(c)				
W18-10	BM	(c)				
W18-11	BM	(c)				
W18-12	BM	(c)				
W19-3					SA	31
W19-5	M	1.9	M	117	M	44
W19-7	BM	(c)				
W21-1						61
W22-1	M	15			Q	1.5
W22-2	BM	0.13				
W22-13	BM	0.17	BM	1830	BM	4.4
W22-19	M	<0.08			M	1115
W22-20	M	0.14			M	300
W22-21	BM	1.1				
W22-22	BM	0.36	SA	445	SA	0.6
W22-26	BM	25	BM	17500	SA	326
W22-38	BM	0.18				
W23-1	BM	(c)				
W23-2	BM	(c)				
W23-3	BM	(c)				
W23-4	M	(c)	M	1600	SA	4.2
W23-7	BM	(c)				
W26-3	M	(c)	M	1.5	M	3.1

(a) Gross Beta is calculated as ^{106}Ru.
(b) The ^{106}Ru Concentration Guide is not strictly applicable to an unknown mixture of beta emitters.
(c) Indicates that the concentration was less than the analytical limit.
No entry indicates no analyses were performed during the 6-month period.
Sampling Frequency Code: SA - Semiannual; Q - Quarterly; BM - Bimonthly; M - Monthly.

TABLE II.3-D-18

AVERAGE GROSS BETA, TRITIUM AND NITRATE CONCENTRATIONS IN 100 AREA AND ASSOCIATED 600 AREA WELLS

	Gross Beta[a] (pCi/ml)		Tritium (pCi/ml)		Nitrate (mg/l)	
Analytical Limit	0.08		1.0		0.5	
Concentration Guide	(b)		3000		45	
Well Number	Sampling Frequency	July-Dec 1973	Sampling Frequency	July-Dec 1973	Sampling Frequency	July-Dec 1973
199-B4-4	SA	(c)	SA	6.8	SA	2.2
B9-1			SA	1.9	SA	1.0
D2-5			SA	16	Q	40
D5-12	SA	(c)	Q	9	Q	36
F5-1			Q	(c)	Q	(c)
F8-1			Q	19	Q	72
H3-1			SA	15	Q	18
K-11			SA	92	Q	(c)
K-20			Q	6.5	Q	(c)
N-3	Q	0.54	Q	140	Q	13
N-4-0	Q	(c)	Q	1060	Q	(c)
N-6	Q	1.3	Q	130		
N-7						
N-8-T						
N-10-P	Q	0.10	Q	59	Q	(c)
N-14	Q	0.25	Q	105	Q	10
N-15	Q	0.19	Q	275	Q	8.4
699-59-32					SA	(c)
60-32					SA	(c)
60-57			Q	2.2	Q	(c)
60-60			Q	2.2	Q	0.7
61-62			Q	2.4	Q	<0.6
61-66			Q	(c)	Q	2.9
62-31					SA	(c)
62-43F					SA	(c)
63-25A					SA	(c)
63-55			Q	1.7	Q	0.6
63-58			Q	3.2	Q	(c)
63-90			SA	(c)	Q	2.4
64-62			Q	1.7	Q	0.8
65-50			SA	1.4	SA	(c)
65-59			Q	1.6	Q	0.7
65-72			Q	2.0	SA	(c)
65-83			Q	2.0	SA	2.1
66-23-0					SA	(c)
66-38-0					SA	(c)
66-39					SA	(c)
66-58			Q	1.8	Q	0.7
66-64			Q	(c)	Q	1.2
67-51-0			SA	(c)	Q	0.8
67-98			SA	(c)	SA	1.9
69-45-0			SA	(c)	SA	(c)
70-68			SA	(c)	SA	1.8
71-30			SA	(c)	SA	17
71-52			SA	3.8	Q	2.7
71-77			Q	(c)	SA	1.8
72-73			SA	(c)	SA	2.2
72-88			SA	16	SA	(c)
72-92-0			SA	23	SA	3.4
74-44			Q	(c)	SA	(c)
74-48			Q	1.7	Q	3.2
77-36			Q	(c)	Q	2
77-54			SA	(c)	Q	4.8
80-43S			SA	(c)	Q	2.4
81-58-0			Q	8.2	Q	0.7
83-47-0			Q	(c)	SA	(c)

TABLE II.3-D-18 (Continued)

	Gross Beta[a] (pCi/ml)		Tritium (pCi/ml)		Nitrate (mg/l)	
Analytical Limit	0.08		1.0		0.5	
Concentration Guide	(b)		3000		45	
Well Number	Sampling Frequency	July-Dec 1973	Sampling Frequency	July-Dec 1973	Sampling Frequency	July-Dec 1973
699-84-35A-0			SA	(c)	Q	(c)
87-55			Q	155	Q	8.9
89-35			Q	(c)	Q	5
96-49-0			SA	7.7	Q	2
97-43-0			SA	8.8	Q	6
101-48B			SA	(c)	SA	0.6

(a) Gross Beta is calculated as ^{106}Ru.
(b) The ^{106}Ru Concentration Guide is not strictly applicable to an unknown mixture of beta emitters.
(c) Indicates that the concentration was less than the analytical limit.
No entry indicates no analyses were performed during the 6-month period.
Sampling Frequency Code: SA - Semiannual; Q - Quarterly; BM - Bimonthly; M - Monthly.

TABLE II.3-D-19

ANALYTICAL DATA - 300 AREA AND ASSOCIATED 600 AREA WELLS

	Gross Beta[a] (pCi/ml)		Nitrate (mg/l)	
Analytical Limit	0.08		0.5	
Concentration Guide	(b)		45	
Well Number	Sampling Frequency	July-Dec 1973	Sampling Frequency	July-Dec 1973
699-S12-3			Q	0.8
S19-E13	Q	(c)	BM	6.9
S27-E14			Q	11
S29-E12			Q	(c)
S30-E15A			Q	2.0
399-1-1	M	<0.09	M	53
1-2	Q	(c)	BM	25
1-3	M	0.09	M	146
1-4	Q	(c)	BM	15
3-1	BM	0.1	M	48
3-8	M	0.3	SA	24
4-1	Q	(c)	BM	12
4-7	Q	0.17	BM	28
4-8		(c)		13
5-1			BM	14
6-1			BM	12
8-2	Q		Q	7.8
8-3			BM	2.7

(a) Gross Beta is calculated as ^{106}Ru.
(b) The ^{106}Ru Concentration Guide is not strictly applicable to an unknown mixture of beta emitters.
(c) Indicates that the concentration was less than the analytical limit.
No entry indicates no analyses were performed during the 6-month period.
Sampling Frequency Code: SA - Semiannual; Q - Quarterly; BM - Bimonthly; M - Monthly.

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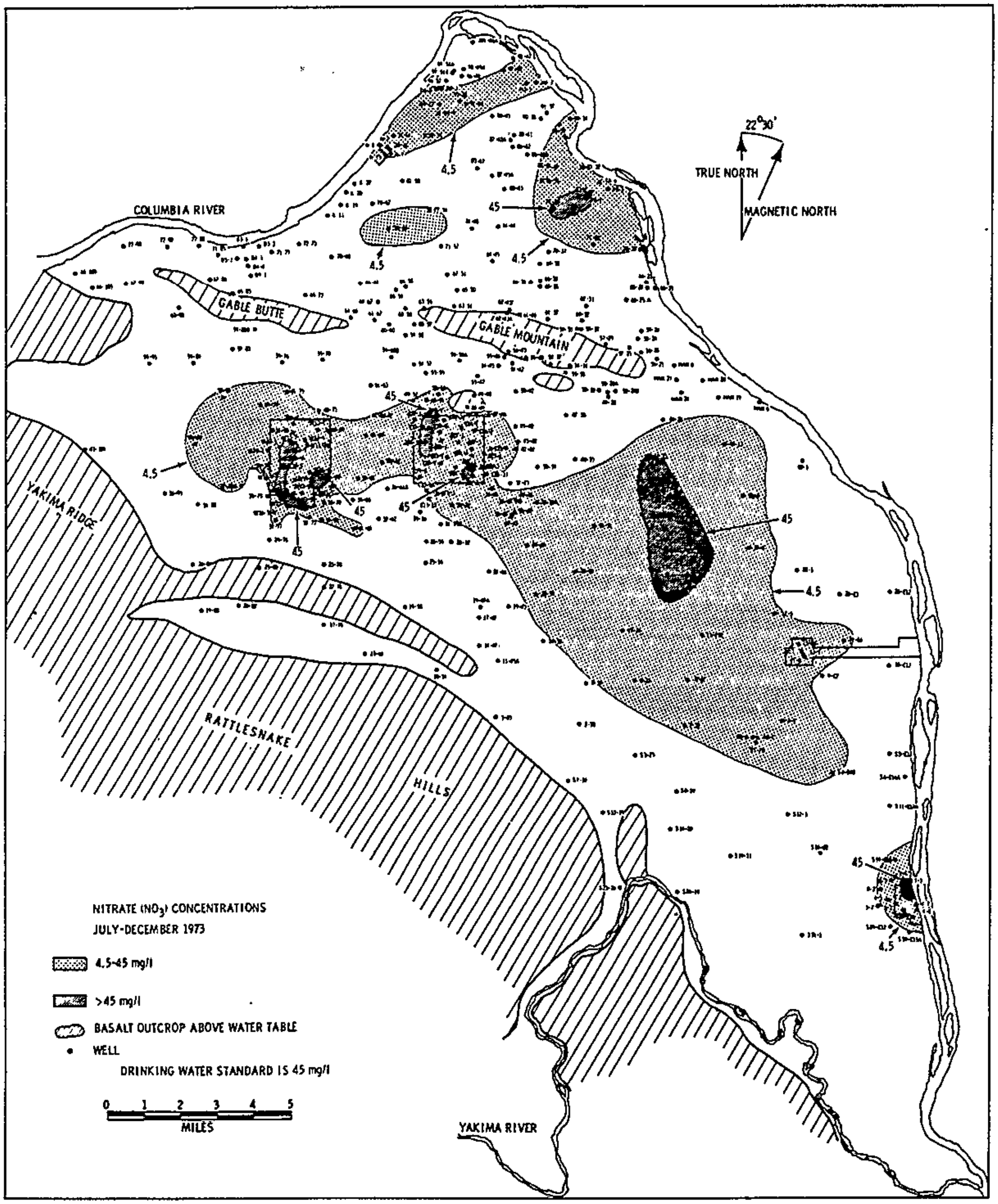

FIGURE II.3-D-20 AVERAGE NITRATE ION (NO_3^-) CONCENTRATIONS FOR 1973 (Drinking Water Standard: 45 mg/l)

with the groundwater. They have formed the plumes of contamination shown in Figures II.3-D-18, -19, and -20 drawn from the average concentrations measured July - December 1973 from the various sampled wells. The stationary assumption is implicit in presenting a semi-annual average map to represent contamination conditions. Evaluations of temporal rates of change in concentration at each well have not been made. A general historical perspective may be obtained by reviewing the series of groundwater reports cited earlier.

The main features shown by the contamination plumes are:

- Relatively little spread of the plumes from the 200 West Area has occurred due to the low groundwater velocities.
- Large plumes from the 200 East Area illustrate flow paths of relatively high groundwater velocity.
- Local contamination exists under the 100 (reactor) Areas from cooling water infiltration and trench disposal at 100-K and 100-N.
- Gross beta contamination under the 300 Area is calculated as ^{106}Ru although it is primarily from uranium waste.
- Residual nitrate contamination remains from pre-Hanford agricultural operations north of Gable Mountain.

Estimates of the inventory of ruthenium, tritium, and nitrate ion in the saturated groundwater of the unconfined aquifer are given in Section II.1.1.4.4 (Volume 1). The operating histories of the various disposal facilities, indicating when the effluents were introduced to the environment, are summarized in Table II.1-1 (Volume 1) and Table II.1-B-1 for the reactor areas and Tables II.1-C-3 and -4 for the 200 Areas. Quantities of radionuclides discharged to each disposal site associated with 200 Areas are tabulated in an ARHCO report, ARH-2757, "Radioactive Liquid Wastes Discharged to Ground During 1972." Table II.1-B-7 contains estimated inventories from the 100 Areas cooling water leakage and disposal operations. Table II.1-B-9 presents the estimated discharges to the 100-N Area crib. Input chemical concentrations to the 300 Area pond are shown in Table III.1-26 (Volume 1). Other radionuclides that have been identified in the groundwater include ^{60}Co, ^{131}I (at the 100-N Area), ^{90}Sr, ^{137}Ce, ^{125}Sb, ^{129}I, ^{99}Tc,* and uranium. However, only a few wells near disposal sites have shown these contaminants and the well density does not allow for definition of the small plumes of contaminants that exist. A gamma scan analysis is used to quantify the ^{106}Ru, ^{60}Co, ^{125}Sb, ^{131}I, ^{137}Cs concentrations.

Groundwater from 3 to 6 wells per year has been analyzed for a few chemical water quality parameters in addition to nitrate ion including sodium, calcium, sulfate, and pH. Values for the chemical ions are given in Table II.3-D-20. In recognition of the need for additional data, a full spectrum of water quality analyses has been initiated for many wells distributed over the Reservation. Results from the first set of samples appear in Table II.3-D-20. In the 300 Area, copper, fluoride and chromate ion analyses are performed on groundwater samples since the fuel fabrication wastewater contains these contaminants.

All routine groundwater analyses are performed by the Battelle-Northwest analytical laboratory. The special water quality studies and duplicate quality assurance analyses have been done by United States Geological Survey Laboratories in Salt Lake City and Denver. Other duplicate analyses have been done by the Washington State Health Services Division which routinely monitors groundwater from three wells surrounding the site of WNP #2 power reactor currently under construction.

In addition to the identification of analytical problems with duplicate quality assurance analyses, a routine program of well maintenance and inspection was instituted in 1974. This includes inspection with a downhole TV system followed by evaluation and maintenance work by a drilling rig, such as cleanout of sand and silt, brushing the casing, perforating, and well development by pumping. These procedures help insure adequate communication between the borehole and the aquifer so a representative groundwater sample is obtained. In early 1974 extensive revisions in the organization and management responsibilities for the routine groundwater monitoring program were begun. One major addition to the program will be a comprehensive quality assurance program covering all phases of sampling, analysis evaluation and reporting. Two years will be required to fully implement these plans.

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* Recently, a more comprehensive analysis for ^{129}I (half life, 1.6×10^7y) was added to the groundwater monitoring program. Due to the low energy of the beta and gamma from ^{129}I, a special chemical separation is required and newly developed analysis methods are now available. Preliminary indication is that ^{129}I in the groundwater may have an environmental importance comparable to ruthenium and tritium. The first results will be reported in the next annual monitoring report "Radiological Status of the Groundwater Beneath the Hanford Project for 1974" to be issued during 1975. Groundwater concentrations of ^{99}Tc are found to be less than ^{106}Rh. The routine monitoring program has measured ^{106}Rh concentrations with special samples for ^{99}Tc on an intermittent frequency. The ^{106}Rh was considered to be a good measure of the position of the rapidly moving radionuclides other than tritium and ^{129}I.

TABLE II.3-D-20

WATER QUALITY RESULTS FROM VARIOUS WELLS SAMPLED NOVEMBER 1974[a]

Quality Component		Well 699-2-3	Well 699-42-12	Well 699-Han-19	Well 699-S11-E12A	Well 699-27-8	Well 699-69-38	Well 699-S3-25	Well 699-33-56	Well 699-49-55
Alk, Tot (as $CaCO_3$)	mg/l	126	118	138	126	119	258	125	167	94
Arsenic Diss	μg/l	14	8	10	12	9	3	8	5	11
Bicarbonate	mg/l	153	144	168	153	145	314	152	204	115
Bromide	mg/l	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2
Calcium Diss	mg/l	44	41	31	39	56	72	51	42	55
Carbon Dioxide	mg/l	3.1	2.3	3.4	2.4	2.3	16	3.1	6.5	1.5
Carbonate	mg/l	0	0	0	0	0	0	0	0	0
Chloride Diss	mg/l	8.9	13	3.1	5.8	13	14	23	7.6	24
Chromium Diss	μg/l	0	0	0	0	0	0	10	0	0
Chromium Hexavalent	μg/l	3	6	0	0	3	0	0	0	0
Color		3	0	0	0	0	8	0	3	3
Conductivity	μmhos/cm	418	440	321	352	486	704	513	429	601
Copper Dissolved	μg/l	8	2	2	8	1	3	12	9	1
Cyanide	mg/l	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.00	0.00
Fluoride Diss	mg/l	0.3	0.4	0.4	0.3	0.2	0.1	0.5	0.3	0.3
Hardness Noncarb	mg/l	30	42	0	17	70	0	60	0	100
Hardness Total	mg/l	160	160	110	140	190	220	190	160	200
Hydroxide	mg/l	0	0	0	0	0	0	0	0	0
Iodide	mg/l	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.00
Iron Diss	μg/l	60	30	50	330	20	330	1600	2400	180
Iron Ferrous	μg/l	40	30	50	60	20	260	90	200	120
Magnesium Diss	mg/l	11	14	7.1	11	12	8.8	14	13	15
Nitr. NO_2 As NO_2 Dis	mg/l	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.03	0.00
Nitr. NO_3 As NO_3 Dis	mg/l	22	28	4.2	22	58	15	0.27	11	12
Nitrogen NH_4 Asn Tot	mg/l	0.06	0.01	0.02	0.04	0.04	2.3	0.03	0.06	0.03
Nitrogen NO_2 Asn Dis	mg/l	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00
Nitrogen NO_3 Asn Dis	mg/l	5.0	6.4	0.95	4.9	13	3.4	0.06	2.4	2.8
NO_2 + NO_3 As N Diss	mg/l	5.0	6.4	0.95	4.9	13	3.4	0.06	2.4	2.8
PH		7.9	8.0	7.9	8.0	8.0	7.5	7.9	7.7	8.1
Phosphorus Tot As P	mg/l	0.02	0.01	0.03	0.05	0.02	1.5	0.06	0.02	0.08
Potassium Diss	mg/l	6.3	5.4	5.4	4.6	6.4	13	7.3	5.8	7.7
Residue Dis Calc Sum	mg/l	270	285	216	238	318	429	308	284	398
Residue Dis Ton/Aft		0.37	0.39	0.29	0.32	0.43	0.58	0.42	0.39	0.54
SAR		0.7	0.8	1.1	0.6	0.6	1.9	0.8	0.9	1.3
Selenium Diss	μg/l	3	3	1	1	2	0	1	2	1
Silica Diss	mg/l	35	39	37	39	36	23	28	39	36
Sodium Diss	mg/l	19	24	25	16	19	64	26	27	41
Sodium Percent		20	24	32	19	17	37	23	26	30
Sulfate Diss	mg/l	48	49	20	25	46	64	81	36	150
Turbidity (JTU)		1	1	1	1	1	1	3	9	10
Water Temp (DEG C)			17.5	17.5	17.5	16.5	14.5	18.5		

(a) Analysis by Central Laboratory, USGS, Salt Lake City, Utah.

A routine program of hydrological measurement is also carried on at the Hanford Reservation, including quarterly water level measurements at about 330 wells and semi-annual preparation of a water table map for the Reservation. Temperature logging of the wells has also been done on an intermittent basis. The most recent temperature logs of the wells were obtained in January 1974. Figure II.3-D-21 shows the temperature distribution at the surface of the unconfined aquifer at that time. The residual heat from the previous reactor operations is evident, as is the thermal plume emanating from the 200 Areas. Relatively warm surface water near the basalt outcrops indicates recharge to the unconfined aquifer from the lower confined zones. Several areas of temperature anomaly exist with values both above and below those expected for the local area. Vertical circulation within the various well bores probably accounts for many of these anomalies. Columbia River recharge effects on the temperature can be seen along the river boundary.

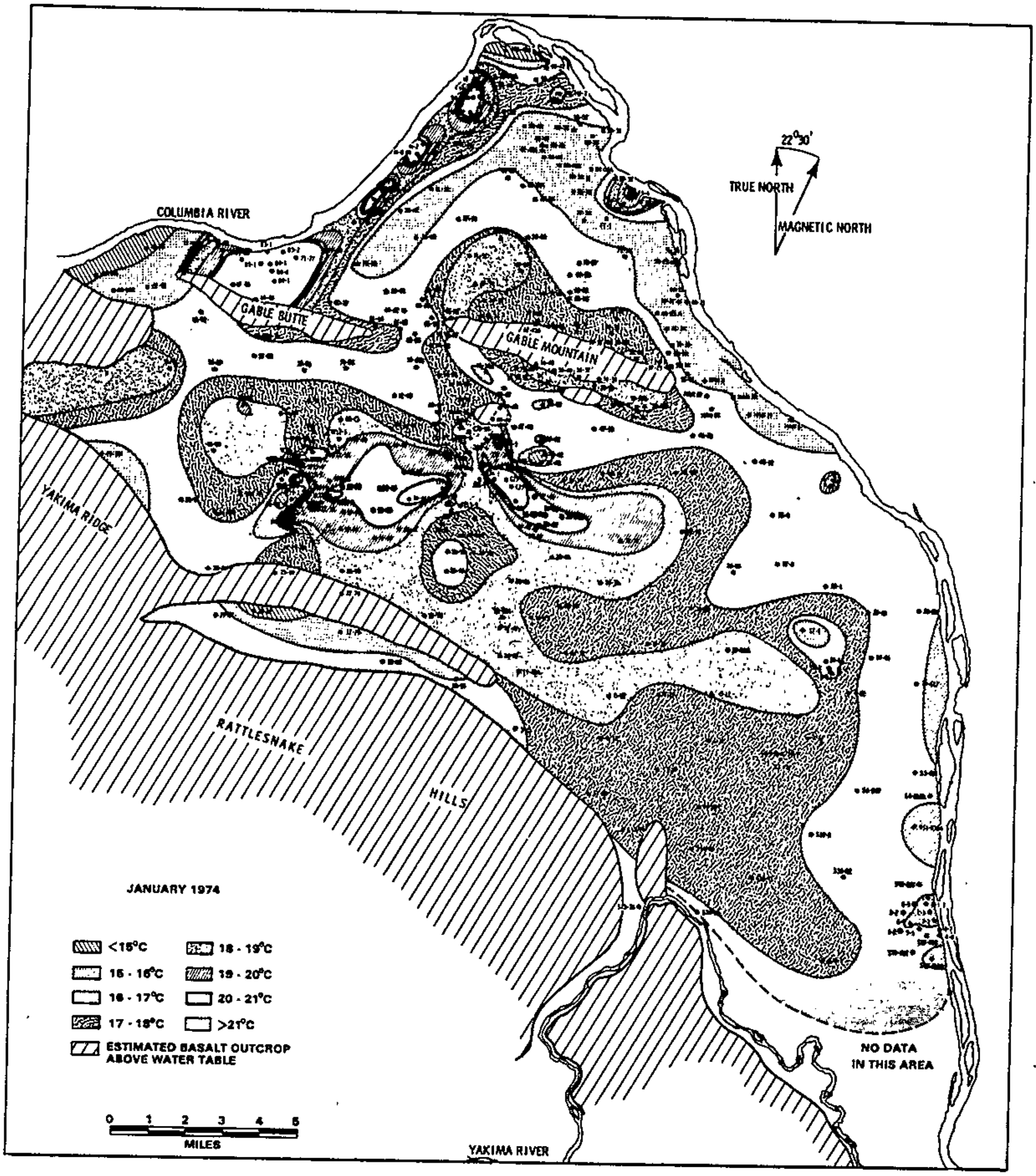

FIGURE II.3-D-21 TEMPERATURE DISTRIBUTION AT THE WATER TABLE (January 1974)

In general, the thermal plumes reflect the same patterns of groundwater movement as do the radioactive contamination plumes. However, movement of process water to the east from 200 West Area is more apparent from the thermal map than from the contamination map. The older gross beta maps do show more of this eastward-tending plume. Most of the ruthenium, the prime beta emitter in this plume, has decayed. Reactor groundwater mounds contained water on the order of 70 to 90°C. The residual heat from these mounds can be seen in Figure II.3-D-21 under the northern part of the Reservation.

Continuous water level recorders are used for special investigations in conjunctions with a thermobarograph. The measured water level histories of the various wells have been published[65] along with selected water table maps covering the 1944-1973 period.

II.3-D.4.6 Effects of Waste Disposal on the Unconfined Aquifer [X.18]

100-N Area

The disposal of radioactive liquid waste to the 1301-N crib and trench is the source of groundwater contamination and resulting transport to the Columbia River. The normal flow rate is 0.33×10^6 ft^3/day with the average radionuclide concentrations[74] shown in Table II.3-D-21 and the representative chemical composition shown in Table II.3-D-22. The discharged liquid waste seeps down to the water table, about 55 feet below the crib, and then moves toward the Columbia River; the minimum horizontal crib-to-river distance is about 800 feet. The most recent studies show minimum field-measured travel times from the crib to the riverbank springs to be 5 to 8 days.[75] An estimated 20% of the flow from this crib reaches the river along the shortest travel paths while the remainder flows to the river along flowpaths having estimated travel times of up to 20 years.

Computing the ratios of crib input to riverbank spring output concentrations gives values of 0.002 to 0.034 for those nuclides for which data are available. At the riverbank springs, ^{131}I and ^{90}Sr were present in 1972 at average concentrations which exceed the Concentration Guides[70] for release of water soluble radionuclide compounds into the uncontrolled environment; the Concentration Guides are exceeded by factors of 1.15 for ^{90}Sr and 2 for ^{131}I. In 1973, only ^{131}I was above the Concentration Guide by a factor of 4.6. Dilution in the river quickly reduces these concentrations to well below the applicable Concentration Guides. All other radionuclide concentrations at the riverbank springs are below their respective Concentration Guides.

TABLE II.3-D-21

1301-N CRIB INPUT RADIONUCLIDE DATA AND RIVERBANK SPRINGS DATA, 1973

	To the 1301-N Crib			Seepage from Crib to River via Springs		
Radionuclide	Average Concentration pCi/ℓ	Peak Concentration pCi/ℓ	Total Released Ci/yr	Average Concentration pCi/ℓ	Peak Concentration pCi/ℓ	Total Released Ci/yr
^{3}H	1.5×10^5	1.3×10^6	480	ND	1.7×10^6	480
^{51}Cr	5.0×10^4	4.4×10^5	160	4.0×10^2	3.6×10^3	0.5
^{54}Mn	1.6×10^5	1.1×10^6	500	7.0×10^1	2.4×10^3	0.1
^{58}Co	8.7×10^3	7.6×10^4	23	3.0×10^1	1.1×10^3	0.005
^{59}Fe	2.4×10^5	1.9×10^6	650	4.6×10^1	4.8×10^3	0.08
^{60}Co	1.1×10^5	1.4×10^6	320	2.9×10^2	7.3×10^3	0.5
^{90}Sr	4.9×10^3	1.5×10^4	16	1.7×10^2	8.4×10^2	0.3
^{95}ZrNb	9.6×10^4	5.9×10^5	410	3.2×10^1	2.3×10^3	0.04
^{99}Mo	1.6×10^5	1.8×10^6	1260	4.0×10^2	1.0×10^4	0.3
^{103}Ru	2.4×10^4	7.3×10^5	80	ND	ND	ND
^{106}Ru	5.6×10^4	8.0×10^5	190	ND	ND	ND
^{131}I	8.3×10^4	6.6×10^5	390	1.4×10^3	7.0×10^3	2
^{133}Xe	1.0×10^5	5.9×10^5	520	9.8×10^2	5.6×10^3	0.7
^{134}Cs	1.4×10^4	5.7×10^4	23	ND	ND	ND
^{137}Cs	1.5×10^4	4.2×10^4	46	2.5×10^1	1.9×10^2	0.05
^{140}BaLa	1.2×10^5	1.1×10^6	460	1.3×10^2	2.0×10^3	0.2

ND - No Data

TABLE II.3-D-22

CHEMICAL CONCENTRATIONS AT 100-N AREA, AUGUST 1972

	Riverbank Springs (mg/l)	Ambient River Concentration (mg/l)
Sulfate	5.5	4.5
Calcium	24.5	17.
Chromium	20.	0.1
Nitrate	2.7	0.1
Total Solids	123.	81.
Aluminum	50.	80.
Iron	25.	75.
Magnesium	3.	3.
Ammonia	<0.1	<0.1
Nitrite	<0.002	<0.002
Strontium	0.080	0.120

The disposal of the nonradioactive chemicals is insignificant for all but chromium, which occasionally can be detected in the river downstream. Since 1972 the chromium discharges have been eliminated by recirculation of the stream containing the chromium. As shown in Table II.3-D-22, the concentrations of the other chemicals are near the ambient concentrations in the river.

200 Area

Waste management operations in the 200 Areas affect the quality of the groundwater under the Hanford Reservation in two major ways. First, the disposal of liquid waste to cribs and trenches is the source of the radionuclide inventory on the soil and in the groundwater described in Appendixes II.1-B, C and E. Second, the disposal of large volumes of process cooling water has had a significant effect on the elevation of the groundwater table of the unconfined aquifer.

The sorbed contaminants, most fission products and all transuranic elements travel at a slower rate than the groundwater flow and many of these contaminants decay before moving more than a few thousand feet from the disposal site. Most of the sorbed contaminants remain on the soil columns and do not reach the water table. The radiological status of the groundwater near the surface of the unconfined aquifer is monitored regularly. The gross beta (calculated as ^{106}Ru) plumes and the tritium plumes were discussed in the preceding section.

300 Area

Discharges to the 300 North Process Pond, the sewage leach trench, the 384 ash pits, the 331 leach trench (which was taken out of service at the end of 1973) and the 315 filter plant are sources of liquid waste disposal to the ground in the 300 Area. However, only the 300 North Process pond and the sewage leach trench have significant flow rates; these average 0.4 x 10^6 ft^3/day and 0.064 x 10^6 ft^3/day, respectively. With the exceptions of fluoride and nitrate ions, the input concentrations to the North Process Pond and the 331 leach trench are below the Concentration Guides for Drinking Water Limits for release to uncontrolled areas. The average fluoride and nitrate ion concentrations are 35 to 40% above their respective drinking water limits.

The minimum time required for seepage from the North Process Pond to travel the minimum distance (about 250 feet) to the Columbia has been estimated at about 3 days. In view of the local groundwater potential surface configuration, about 70% of the seepage from this pond is assumed to move directly east to the river. Groundwater monitoring wells near the North Process Pond and the sanitary leach trenches are analyzed regularly for gross alpha and gross beta activity and nitrate, chromium, and fluoride ion concentrations. Average concentrations shown by Well 399-1-1 (between the North Pond and the Columbia River) were factors of 2 to 4 below the input to the pond.[77] Those from Well 399-1-3 (between the pond and the trench) were factors of 1.4 to 2 lower, except fluoride ion (which was the same) and nitrate ion (which was a factor of 1.3 higher).

Riverbank seepage springs located about 1 mile north of the 300 Area and directly east of the South Process Pond or about 100 feet downstream of the sanitary leach trenches are sampled regularly. Historically, the South Process Pond has contributed to the flow of these springs. Except for a few days in 1972 and 1974, the South Pond has been out of service since 1968. These springs are not on the shortest flow path from the North Process Pond to the river; however, they are near the shortest flow path from the sanitary leach trenches. Travel times of 6 to 7 days from the North Process Pond to the riverbank seepage springs were observed using the chromium ion as a tracer.[78]

These springs also became submerged at higher river stages on a daily to weekly frequency; thus, dilution by river recharge greatly affects the discharge concentrations observed at this sampling location. For 1972, the yearly average nitrate ion concentrations for the North Process Pond and the riverbank spring were equal at 61 mg/liter. Complete chemical analyses of the spring samples were made through the first quarter of 1972. The first quarter averages are presented in Table II.3-D-23 along with corresponding groundwater concentrations. On this quarterly basis, significant concentration reductions for chloride ion, copper ion, and uranium appear in the groundwater reaching the riverbank spring downstream from the Process Pond. The fluoride and nitrates ion concentrations were reduced to below drinking water limits; a smaller concentration reduction was observed for sulfate and chromium ions. For comparison, samples of riverbank springs upstream of the 300 Area show a first quarter 1972 nitrate ion concentration of 0.55 mg/liter and fluoride ion concentration of 0.15 mg/liter. The sulfate concentration is above the ambient river concentration shown in Table II.3-D-23; no other chemicals were measured at these springs. Dilution by riverbank recharge is assumed to be the major cause of the concentration reductions. Very little of the uranium is being retained by the soil.[78] Therefore, the 300 Area North Process Pond appears to be releasing nitrate ion to the Columbia River at an average annual concentration above the drinking water limit. However, dilution by riverbank recharge tends to reduce the concentration at the surfaces of seepage into the Columbia River. The potential exists that the groundwater entering the river may periodically exceed the drinking water limit for fluoride ion.

TABLE II.3-D-23

AVERAGE CHEMICAL CONCENTRATIONS FOR THE FIRST QUARTER 1972

(mg/ℓ)

Element	North Pond Input	Riverbank Springs	Springs Range May 1971	Through March 1972	Well 399-1-1	Well 399-1-3
Cl^-	11	3.9	1.1	16		
Cu	3.4	<0.05	0.006	0.08		
Fe	0.14	0.016	0.002	0.15		
F^-	3.3	0.58	<0.05	1.8	0.66	1.9
NO_3^-	68	20	1.2	212	37	130
SO_4^{--}	28	21	13	40		
Cr^{+6}	0.004	0.003	0.001	0.023		
pH	7.4	8.0	7.4	8.2		
U	0.047 pCi/ml	0.019 pCi/ml	0.016 pCi/ml	0.20 pCi/ml		

Bacterial and biological water quality parameters are routinely measured at the 300 Area sanitary waste leaching trench, which is located about 400 feet from the Columbia River shoreline, as well as at the seepage springs at the riverbank; Table II.3-D-24 shows the sample results for 1972. The coliform counts at the riverbank springs are within the Environmental Protection Agency (EPA) standards for a public drinking water supply. Similarly, the BOD levels are well within the EPA's discharge criteria for publicly-owned secondary treatment plants for a 30-day average. In view of the Columbia River water quality data presented in Table II.3-D-24, the 300 Area sanitary waste leach trench appears to have a negligible impact on the Columbia River.

New trenches, which will be located about 1,200 feet from the Columbia River, are planned to replace the North and South Process Ponds. The primary advantage will be to increase the minimum travel time of groundwater flow to the river, thus affording a greater chance for dilution and radioactive decay of the waste material entering this disposal facility. In view of the operational change previously described, only an accident would cause significant concentrations of contaminants to enter the new wastewater trenches.

TABLE II.3-D-24

BIOLOGICAL MEASUREMENTS OF SAMPLES COLLECTED FROM THE 300 AREA LEACHING TRENCH AND ITS ASSOCIATED RIVER SHORELINE SEEPAGE AREA - 1972

	300 Leaching Trench		
Date	Coliform N/100 ml	Enterococci N/100 ml	BOD mg/ℓ
1/11	330,000	3,300	7.0
2/8	190,000	5,000	6.7
3/14	1,280,000	6,500	5.9
4/4	720,000	29,000	2.6
6/20	640,000	7,500	4.2
7/11	1,320,000	12,000	4.0
8/8	500,000	23,000	4.6
9/5	3,000,000	17,000	3.6
10/3	850,000	33,500	2.0
11/14	320,000	11,000	1.9
12/12	264,000	8,000	1.4
Average	855,818	14,164	4.0
EPA Treatment Plant Criteria			30.

	River Shoreline Seepage Area		
Date	Coliform N/100 ml	Enterococci N/100 ml	BOD mg/ℓ
1/11	23.	16.	3.4
2/8	2.	5.	1.2
3/14	7.	4.	3.1
4/4	6.	10.	3.4
6/20	105.	20.	4.0
7/11	250.	28.	4.0
8/8	60.	17.	2.8
8/22	130.	25.	1.2
9/5	30.	13.	0.45
9/19	98.	55.	1.9
10/3	25.	18.	1.6
10/24	115.	148.	1.6
11/14	6.	120.	1.4
12/12	8.	7.	1.8
Average	62.	35.	2.3

(Federal Water Quality Standards for Public Water Supply)

Desirable <100. Permissible <10000.

400 Area (FFTF)

The only waste discharge to ground at the Fast Flux Test Facility (FFTF) is a combination sanitary sewage and construction waste water stream with an average rate of 2,700 ft^3/day which has an insignificant effect on the groundwater flow patterns and water quality. Under operating conditions, this discharge will be monitored to ensure that it is free of radioactivity.

600 Area and Other 100 Areas

Sanitary sewage leach trenches and tile fields are in operation at 100-B/C, 100-K, and 100-D Areas with the maximum average discharge rate being 1,300 ft^3/day (100-K Area). Various other facilities in the 600 Area, including fire stations, road maintenance building, BNW Atmospheric Physics, etc. also have sanitary sewage discharges to leach trenches, with a maximum average rate of 400 ft^3/day (Atmospheric Physics). The impact of these minor sources is negligible.

Sanitary waste in plant areas is generally treated by a septic tank and tile leach lines or leach trenches for disposal of the water. The volumes of these disposals are relatively small, and penetration rate to the water table is generally measured in years. In the shallow soils, around lines buried 18 inches to 36 inches deep, aerobic bacterial action prevails with high biological purification. During summer months, large quantities of the disposal will be lost to the atmosphere by evaporation.

II.3-D.5 The Confined Aquifers

The limited amount of research to date indicates that a number of confined aquifers are underneath the Hanford Reservation. Relatively impermeable confining beds commonly include the individual basalt flows where they are continuous and greater than about 50 feet thick and the silts and clays of the lower part of the Ringold Formation.[79] Within the basalt sequence, groundwater is transmitted primarily in the interflow zones, either in sedimentary beds or in the scoria and breccia zones forming the tops and bottoms of the flows.[80,81] Some of the basalt flows in the Pasco Basin have been eroded, particularly in the anticlinal ridges. In some locations the basalts are highly jointed and contain breccia, pillow and palagonite complexes through which groundwater can move. Consequently, hydraulic potential differences between water-bearing zones in the upper part of the basalt sequence are small, over hundreds of feet of depth. The lowermost Ringold Formation silts and clays are of variable thickness. Distinct hydraulic potential differences have been observed below the silts and clays of the unconfined aquifer. About 90 wells on the Hanford Reservation have been drilled to basalt. Thus data on the confined aquifers in the basalt flows are scarce and inadequate to fully characterize the confined aquifers. The identified recharge area is from the Yakima River at Horn Rapids. The piezometric map in

Figure II.3-D-22 suggests recharge from the upper Cold Creek Valley with flow toward a potential trough under the Columbia River. The Columbia Basin Irrigation Project to the northeast and east, and the Columbia River behind Priest Rapids and Wanapum dams to the northwest are recharge areas where basalt is exposed and covered by unconsolidated deposits which are saturated perennially. A possible minor recharge site is adjacent to Gable Butte-Gable Mountain anticline near the center of the Reservation.

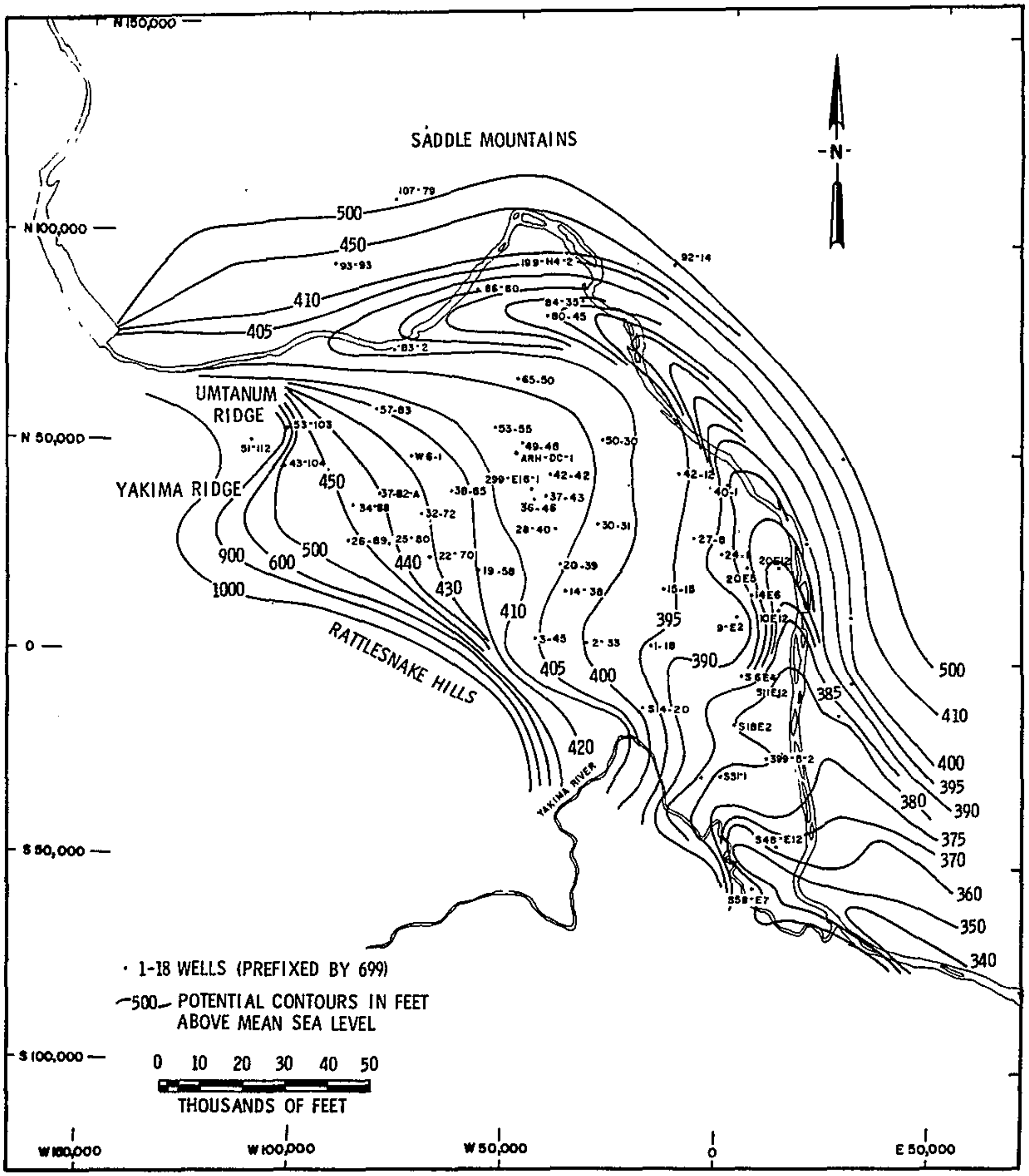

FIGURE II.3-D-22 HYDRAULIC POTENTIAL DISTRIBUTION OF THE UPPERMOST CONFINED AQUIFER - 1970

The piezometric or hydraulic potential map for the confined aquifer in Figure II.3-D-22 was based on measurements made in 1970. In general, the hydraulic potential observed in the confined zones above the basalt is greater than in the overlying unconfined aquifer. The main exception is in the vicinity of the 200 Area recharge mounds which have raised the potential in the unconfined aquifer. At ARH-DC-1 there is a decrease in hydraulic potential at a depth of about 3,600 feet.[81] The lowest observed potential was 365 feet at a depth of 4,000 feet which is higher than the normal 340-foot Lake Wallula pool elevation. The decrease in potential with depth indicated that there is a downward flow to the water-bearing zone at 4,000 feet. Groundwater flow in this aquifer is also to the southeast with possible discharge into the Columbia River somewhere below Lake Wallula. However, the flow rates are expected to be quite small due to the low transmissivity range of this water-bearing zone. Data from the area of the Horse Heaven Hills indicates that groundwater below the 3,600-foot depth must discharge to the Columbia River north of these hills. Groundwater in the lower confined aquifers does not appear to cross the major anticlinal divides that define the Pasco Basin.[81]

Seven wells that penetrate the aquifer confined by the Ringold silts and clays showed a 1- to 2-foot head rise during the 1963-1964 period. All of these wells are adjacent to the Columbia River. Wells further from the river showed no significant rise in water level. Water level data from the U.S. Bureau of Reclamation show that water levels in the unconfined aquifer in Franklin County were rising rapidly, reflecting an increase in potential at recharge sites to the northeast of the Hanford Reservation. These data strongly suggest that the hydraulic potential rise was caused by recharge from the Columbia Basin Irrigation Project.[79] Water level trends in most of these wells continue upward, as shown in the hydrographs of Figure II.3-D-23.

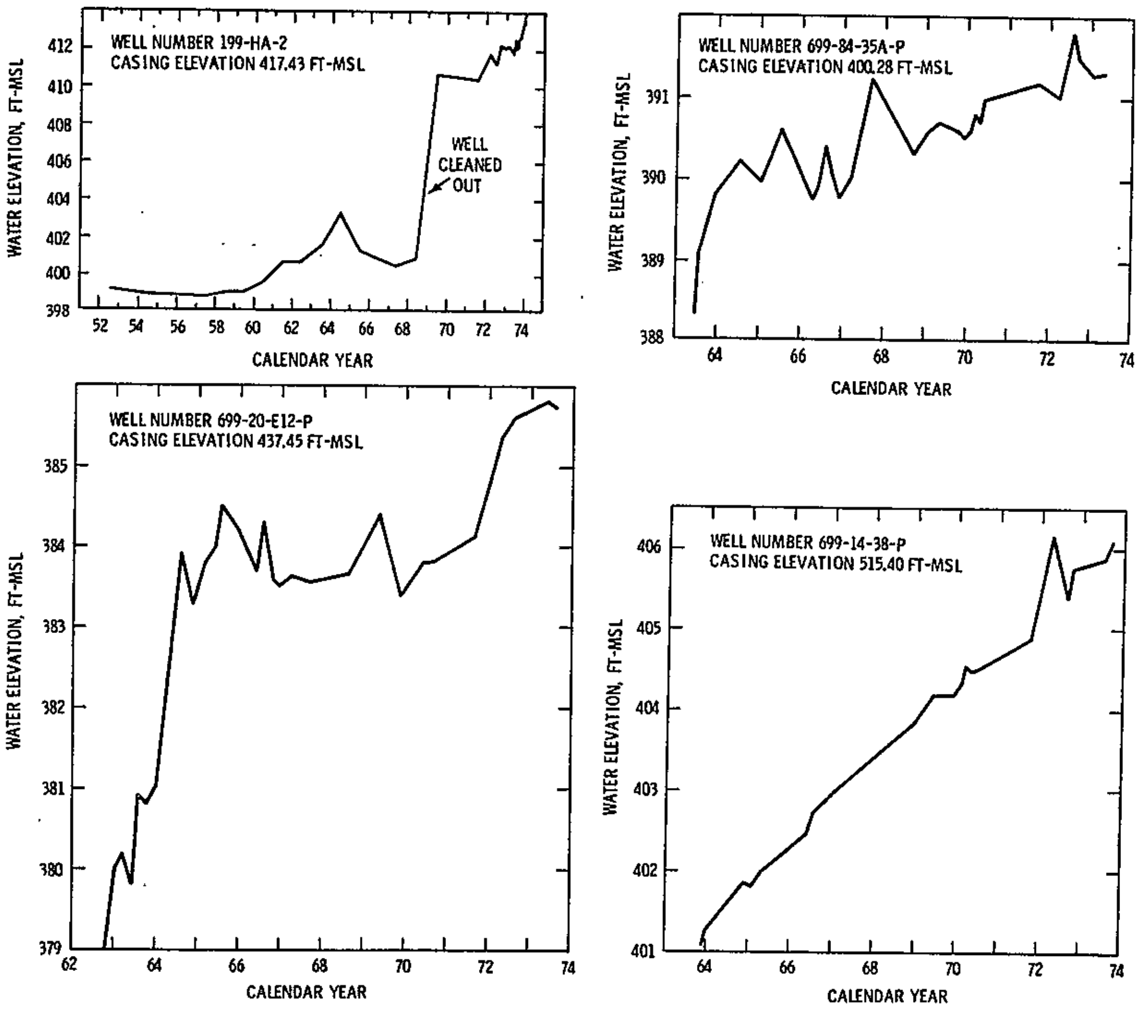

FIGURE II.3-D-23 WELL HYDROGRAPHS FOR THE CONFINED AQUIFER

In 1970 and 1971, twenty-three wells that penetrate the uppermost confined aquifer were pump tested and transmissivity values calculated. Valid data were obtained from seventeen of the tests and are presented in Table II.3-D-25. Values of transmissivity ranged from 2.3 square feet per day to 2,400 square feet per day. Corresponding hydraulic conductivities based on estimated aquifer thicknesses were less than 0.1 foot per day to about 15 feet per day.[69]

Some data on the aquifer properties of the lower confined aquifers are available from the deep drilling project, Well ARH-DC-1.[81] This well was drilled to a depth of 5,661 feet and is located near Well 699-48-49. At this well the basalt at depths from 362 to 1,200 feet deep had a transmissivity of about 695 square feet per day. A sedimentary unit which occurs in this zone from 830 to 936 feet has a transmissivity of about 355 square feet per day. A dense basalt zone from 960 to 1,090 feet has a transmissivity of 0.2 square feet per day. One significant water-bearing zone 10 feet thick which occurs at 3,230 feet has a transmissivity of about 68 square feet per day. Corresponding hydraulic conductivities were computed by factoring out the aquifer thicknesses from the transmissivities. Values from 0.0016 to 0.029 feet per day were calculated. Five significant basalt flow contacts had high hydraulic conductivities on the order of 8.7 feet per day. The five zones are located at depths of 1,200, 2,050, 2,600, 3,200, and 4,000 feet at Well ARH-DC-1. Water-bearing sedimentary interbeds are centered at 500, 650, and 900 feet and range in thickness from 25 to 100 feet. The bed at 900 feet, which is about 100 feet thick, consists of well sorted medium sand of moderate permeability. Its hydraulic conductivity is about 3.5 feet per day, making it the most productive aquifer penetrated by this well.

Only one measurement of the storage coefficient has been made in the confined aquifer above the basalt. (The storage coefficient is the change in volume of water per unit horizontal area caused by a unit change in the potential head. For the confined aquifer, it reflects the compressibility of the water and the elastic properties of the porous matrix.) The results at Well 699-14-E6 gave values ranging from 0.0005 to 0.0007 which are lower than those measured in the Ringold Formation.[79]

The water quality and radiological status of the groundwater in the confined aquifers have been measured with less detail and regularity than for the unconfined aquifer. The most extensive measurements have been for the tritium content. Table II.3-D-26 gives the results of the most recent (1968-1970) tritium measurements and the volume pumped before sampling. The differing well structures make a representative sampling of confined aquifer water difficult. Most values are below the routine tritium detection limit for water samples from the unconfined aquifer (500 to 700 pCi/liter).

TABLE II.3-D-25

CONFINED AQUIFER PUMP TEST RESULTS

Well Number	Transmissivity (ft^2/day)	Hydraulic Conductivity (ft/day)
199-B3-2	3.5	0.1
199-H4-2	2.3	<0.1
299-W11-2	100	0.1
399-5-2	6	<0.1
699-S18-E2	13	1.3
699-S11-E12	35	0.9
699-S6-E4-C	1500-2400	9-15
699-S1-7-8	1600-2200	10-14
699-10-E12	190-210	19-21
699-14-E6	470-760	7-11
699-14-38	400	130
699-20-E12	350	9
699-20-E5	430	1.2
699-24-1	87	0.9
699-28-40	4.8	0.3
699-34-88	24	0.1
699-84-35	4.3	0.4

TABLE II.3-D-26

TRITIUM IN HANFORD WELLS TAPPING THE CONFINED AQUIFER

Well Number	Samples Results[(a)] (pCi tritium/liter)	Volume Pumped Prior to Sampling (gallons)
199-H4-2	600 ± 70 730	NM 95,000
299-W11-2-P	3,900 + 320 - 640	500
699-S11-E12A	610 ± 29	Flowing Well
699-2-33-P	<500	NM
699-10-E12-P	<500 1,500 ± 56 <500 <500	NM 1,600 700 700
699-14-E6-P	550 + 77 610 - 35	2,000 NM
699-14-38-P	640	NM
699-15-15A	540	NM
699-20-E12-P	<500	NM
699-20-E5-P	<500 <500	NM NM
699-24-1-P	760 <500	NM NM

(a) The Concentration Guide for public drinking water, as given in the ERDAM-0524 Appendix, Table 2, is 3×10^6 picocuries per liter.

NM - Not Measured.
Detection limit 500 to 700 pCi/liter

Table II.3-D-27[81] gives the results of chemical analyses from wells that tap basalt aquifers under the Hanford Reservation. There is a decreasing trend with depth for calcium, magnesium, and sulfate and an increasing trend with depth for sodium and chloride, as observed in ARH-DC-1.

TABLE II.3-D-27

CHEMICAL ANALYSES OF GROUNDWATER SAMPLES FROM WELLS DRAWING WATER PRINCIPALLY FROM BASALT UNDER THE HANFORD RESERVATION (Physical Data)

HANFORD WELL NUMBER	DATE COLLECTED	TEMPERATURE (°C)	SILICA (SiO_2)	ALUMINUM (Al)	IRON (Fe)	MANGANESE (Mn)	CHRONIUM (Cr) (TOTAL)	NICKEL (Ni)	COPPER (Cu)	LEAD (Pb)	ZINC (Zn)	CALCIUM (Ca)	MAGNESIUM (Mg)	STRONTIUM (Sr)	SODIUM (Na)	POTASSIUM (K)	LITHIUM (Li)	BICARBONATE (HCO_3)	CARBONATE (CO_3)	SULFATE (SO_4)
							MILLIGRAMS PER LITER													
11/24-14N1	11/13/70	15	45	0.00	0.03	<0.02	<0.03	<0.05	<0.05	<0.1	0.20	18	8.3	<0.05	12	4.5	<0.02	109	0	15
11/26-34R1 699-S18-51	11/19/70	24	75	0.35	0.05	<0.02	0.03	-----	<0.05	<0.1	<0.01	1.0	0.0	<0.05	122	15	<0.02	154	15	0.0
12/23-28Q1[a]	9/21/70	15.4	36	0.02	0.02	<0.02	0.03	-----	-----	----	0.8	18	7.9	-----	9.0	1.8	-----	93	0	11
12/24-20N1	9/11/70	26	56	0.00	0.08	0.05	<0.03	-----	-----	----	-----	18	11	-----	21	7.7	-----	170	0	0.2
12/28-24N1	9/15/70	19	56	0.14	0.05	0.10	<0.03	-----	-----	----	-----	3.7	0.7	-----	94	11	-----	170	8	29
13/24-25E1 699-52-111	8/27/70	24.2	56	0.09	0.09	0.10	<0.03	-----	-----	----	-----	18	11	-----	26	7.3	-----	180	0	0.2
13/25-30G1 699-53-103	8/27/70	26.9	56	0.08	0.07	0.05	0.03	-----	-----	----	-----	16	8.9	-----	30	8.6	-----	175	0	0.0
13/25-30G1	9/8/70	27	57	0.08	0.08	0.05	0.03	-----	-----	----	-----	16	8.8	-----	30	8.3	-----	175	0	0.0
13/26-35H1[b] ARH-DC-1	5/8/69	----	46	0.1	0.10	0.00	0.00	-----	-----	----	-----	2.1	0.3	-----	79	7.8	-----	199	10	0.0
14/25-1D1 699-107-79	9/17/70	20.4	56	0.02	0.14	0.02	0.03	-----	-----	----	-----	24	8.6	-----	17	11	-----	141	0	24
15/26-28Q1 699-114-60	5/15/69	----	54	0.0	0.06	0.00	0.00	-----	-----	----	-----	11	3.3	-----	4.1	17	-----	139	3	24

HANFORD WELL NUMBER	MILLIGRAMS PER LITER									SPECIFIC CONDUCTANCE (MICROMHOS AT 25°C)	pH	COLOR	ALTITUDE OF LAND SURFACE (FEET)	DEPTH OF WELL (FEET)	DEPTH OF CONTINUOUS UNPERFORATED CASING (FEET)	STATIC WATER LEVEL	
						DISSOLVED SOLIDS		HARDNESS									
	Cl	F	NO_3	PO_4	B	CALCULATED	RESIDUE ON EVAPORATION AT 180°C	$CaCO_3$	NONCARBONATE							DEPTH (FEET)	DATE
11/24-14N1	4.2	0.4	0.0	0.09	0.02	161	---	79	0	219	7.5	0	2860	407	---	220	1970
11/26-34R1 699-S18-51	81	8.5	0.2	0.01	0.49	400	408	3	0	597	8.8	0	1212	1000	739	802	1958
12/23-28Q1[a]	5.1	0.4	4.1	0.18	0.06	139	146	78	2	201	7.2	0	2200	2	---	---	----
12/24-20N1	3.8	0.6	0.0	0.02	0.02	202	204	90	0	276	8.0	0	1060	1200	400	+92	1924
12/28-24N1	29	4.2	0.0	0.13	0.09	324	329	12	0	468	8.7	0	430	755	---	19	----
13/24-25E1 699-52-111	4.4	0.7	0.0	0.03	0.09	213	213	90	0	295	8.0	0	924	777	625	+36	11'28'51
13/25-30G1 699-53-103	4.4	0.7	0.0	0.03	0.11	211	220	77	0	287	8.1	0	836	1110	---	+172	11'28'51
13/25-30G1	4.5	0.7	0.0	0.03	0.07	211	216	76	0	288	8.1	0					
13/26-35H1[b] ARH-DC-1	4.2	1.0	0.1	0.11	0.06	249	252	6	0	344	8.6	0	572	5661	964	166	5'8'69
14/25-1D1 699-107-79	5.0	0.4	0.0	0.03	0.03	215	222	96	0	291	8.1	0	660	938	891	183	6'9'58
15/26-28Q1 699-114-60	4.3	0.3	0.2	0.04	0.04	226	220	41	0	303	8.4	0	770	992	860	317	9'1'53

[a] A DEVELOPED SPRING

[b] WELL ARH-DC-1. SAMPLE TAKEN FROM THE DEPTH INTERVAL OF 540-620 FEET DURING CONSTRUCTION OF THE WELL. WATER LEVEL GIVEN IS THAT FOR THE DEPTH INTERVAL OF 540-620 FEET MEASURED DURING CONSTRUCTION OF THE WELL.

II.3-D.6 Aquifers Across the Columbia River

Very little data are available on the groundwater aquifers to the north and northeast of the Columbia River. This area has been leased to the State of Washington and the U.S. Bureau of Sport Fisheries and Wildlife and is no longer under direct jurisdiction of ERDA. About 35 wells were at one time in this Wahluke Slope-White Bluffs area, of which 20 remain.[82] The confined basalt aquifers underlie this area, as under the present Hanford Reservation. The unconfined aquifer exists only under the parts of the Wahluke Slope between the higher bluffs and the Columbia River. The Ringold Formation and glaciofluvial sediments form this aquifer.

The Saddle Mountains form the northern boundary to the confined aquifers and are a potential recharge site due to basalt flow outcropping. The Columbia Basin Irrigation Project and the Columbia River behind Priest Rapids and Wanapum Dams are other probable recharge areas. Recharge also results from surface runoff in coulees and ditches.[81] The Columbia River forms the primary discharge boundary for the unconfined aquifer. Seasonal riverbank storage and discharge also takes place as it does on the Reservation side of the river. The remaining sources of recharge to the unconfined aquifer are the irrigation wasteways and ponds that have been constructed since this land was released from ERDA control. ERDA does not monitor observation wells to record the recharge effects of these ponds.

The water table elevations in the unconfined aquifer near the Columbia River range from 370 to 405 feet MSL at the four available observation wells. The hydraulic potentials in the wells that penetrate the confined aquifers average about 50 feet higher. These wells are perforated in several basalt aquifers, precluding representative potential measurements.

The limited amount of information available indicates that the groundwater in the unconfined aquifer across the Columbia River moves toward the river, discharging into it. Some evidence indicates that groundwater in the confined aquifer may be flowing under the present riverbed to a trough of low potential. This flow, mixed with confined aquifer groundwater from under the Hanford Reservation, then moves downstream (with some discharge into the Columbia River) and up through the unconfined aquifer, controlled by the hydraulic conductivity of the confining beds.

Water quality data for the groundwater across the Columbia River consist only of routine nitrate measurements for the confined aquifers and some data given in Table II.3-D-27. No nitrate concentrations above the routine detection limit (0.5 mg/liter) have been observed. Analyses for gross alpha, gross beta, and tritium have been made. The measurements of radionuclide concentrations in the confined aquifers have also shown no detectable concentrations above the routine detection limits.

II.3-D.7 Program Review

The purpose of the Hanford Hydrology Program is to maintain a groundwater surveillance network to assess contamination of the natural water system and to conduct all needed groundwater management operations. Potential groundwater contamination is primarily a function of waste management decisions. A comprehensive review[2,83,84] of the groundwater management and environmental monitoring programs at the Hanford Reservation was initiated in 1973 and completed in 1975. The review, conducted by an independent consultant, revealed that the hydrology program is adequate to predict levels of contaminants present in the groundwater system. No information was found which indicates that a hazard through the groundwater pathway presently exists as a result of ERDA Waste Management Operations at Hanford.[85]

The technical recommendations made as a result of the independent review are listed in the final report[84] by areas of endeavor, with some overlap occurring. All recommendations are summarized in Table II.3-D-28 with note made of the action taken or comtemplated. Decisions will be made as current work indicates the best course of action. Studies are presently underway to refine advanced mathematical models to use results of the hydrologic investigations in forecasting the response of the system to different long-term management decisions. Special emphasis is on improving existing monitoring structures as well as enhancing the data base to be used in the predictive models.

During the last six months, accelerated technical progress in the field of groundwater management has produced the following changes and improvements:

- An inventory has been made of well structures used for radionuclide monitoring. Structures have been selected on the basis of definite clearly spelled out criteria.
- A preliminary gravity survey of the basin conducted using a 600-station gravity network has been completed. A bedrock map based on this survey is being prepared.

- A comprehensive review of all the data available regarding transmissivity and hydraulic conductivity as of 1975 and the generation of various hydrologic maps have been completed.

TABLE II.3-D-28

MASTER PLAN FOR HYDROLOGIC MANAGEMENT

	Initiated	To be Initiated	Future Work	Not Planned	No Decision
Regional Hydrogeology					
Understanding of the regional hydrogeology of the Hanford Reservation - evaluation of the validity of model assumptions	X				
A study of the confined aquifers in the basalt and a study of the Ringold aquifer		X			
Conduct the needed hydrologic tests in the confined aquifers to establish whether or not a model of contamination must be applied to this aquifer			X		
Vadose Flow Model					
Theoretical Work					
• Complete formulation of the mathematical flow regime	X				
• Solution of the numerical algorithm	X				
Experimental Work					
• Determination of water potential vs. depth and time in the lysimeters	X				
• Determination of barometric pressure changes vs. depth and time in the lysimeters		X			
• Determination of the extent of moisture removal by barometric pressure pumping		X			
• Conduct a hydrologic inventory at the lysimeter site		X			
• Correlation of extent of precipitation and infiltration		X			
• Determination of the effect of temperature changes on water potential and water transport		X			
PERCOL Model					
Begin to apply the model directly to as many useful purposes as possible			X		
Extend the model to the case of acid discharges			X		
PST Model					
Improve the efficiency of the numerical algorithm being used	X				
Conduct a thorough check of numerical dispersion					X
Re-examine the problem of tank rupture		X			
Verify that the assumptions required by the present model are satisfied in the Hanford environment	X				
Expand the cooperation with data processing	X				
Test the model with field and experimental data		X			

	Initiated	To be Initiated	Future Work	Not Planned	No Decision
Transmissivity Iterative Routine					
Theoretical Work					
• Improve the efficiency of the computer program	X				
• Develop a storage coefficient calculation to be performed simultaneously with the transmissivity calculation			X		
• Extend the model to account for transient boundary conditions and disposal flow rate variations					X
• Improve the model in the transmissivity determinations					
a) near the mounds underlying the waste disposal sites		X			
b) in areas where small radii of curvature in the streamtube occur, and	X				
c) near impermeable boundaries	X				
• Verify the model		X			
Experimental Work					
• Implement a field program involving geologic, geophysical, and hydrologic work to accurately establish:					
a) the position of the bottom surface of the unconfined aquifer	X				
b) the amount of infiltration, and location of infiltration sites, and	X				
c) the value of transmissivity and storage at various points in the reservation	X				
VTT Model					
Improve the efficiency of the computer program	X				
Check for numerical dispersion especially when the flow velocity is high		X			
Check for the validity of the model assumptions to the Hanford environment	X				
Compare results of the model to observed field water table measurements and where disagreement is noted make a careful scrutiny to establish the reasons for the discrepancy		X			
Transport Model					
Theoretical Work					
• Streamline the numerical algorithm and check the instabilities		X			
• Improve the modeling capability for the tank leak case		X			
Experimental Work					
• Conduct an experimental and field program to expand knowledge of dispersion components and the strontium sorption coefficient in the Hanford Reservation					X

TABLE II.3-D-28 (Continued)

	Initiated	To be Initiated	Future Work	Not Planned	No Decision
Data Bank					
Conduct a complete literature survey of Hanford hydrogeologic publications and related matters	X				
Develop a comprehensive data system covering all wells in the basin to be implemented in the Battelle computer		X			
Establish a comprehensive data cataloging system		X			
Develop the necessary software for the data bank		X			
Permanent Data Monitoring Program					
Implement a hydrologically sound data monitoring program	X				
Establishment of an Interim Contingency Plan					
Using sound water management practices and the data and models presently available, examine various potentially hazardous situations and determine ways to correct the situation. Update the interim contingency plan periodically as model and data improvements warrant it	X				
Definition of the Hydrologic Impact of Waste Disposal					
Precise definition of input and output		X			
Groundwater chemistry analysis of the flow system			X		

	Initiated	To be Initiated	Future Work	Not Planned	No Decision
Water Level Monitoring					
All wells with open intervals of 40 feet or more should be plugged	X				
Piezometers should be used to monitor future episodic events					X
The present retrieval system is awkward, time consuming, and expensive. All head data should be published routinely			X		
Radionuclide Monitoring					
Wells constructed for the radionuclide monitoring program should have identical open intervals. A program should be initiated to determine the optimum well design and the optimum sampling procedures for obtaining comparable samples	X				
The possibility of sample aging should be examined in detail			X		
Complete chemical analyses should be obtained as well as radionuclide content		X			
The data should be reported in its entirety in a systematic fashion					X
The collector, analyst, and interpreter should be separate individuals	X				
A mass balance should be achieved					X

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APPENDIX II.3-E

METEOROLOGY

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II.3-E METEOROLOGY

II.3-E.1 General Climatology

For general climatological purposes, meteorological data from the Hanford Meteorology Station (HMS) are representative of the Hanford site. Much of the information, including figures and tables, used in the following sections was derived from "Climatography of the Hanford Area"[1] which is based mostly on continuous observations at the HMS since 1944. Local topographic features have some influence on prevailing wind directions observed onsite.

Air masses with source regions over the continent and over the Pacific Ocean reach the Hanford Reservation and exert their influence. Summers are sunny, warm and dry, with several hot days. In the winter, frequent changes in the weather are caused by Pacific storm systems carried eastward by prevailing winds and arctic air masses moving southward from Canada.

The Cascade Mountain Range to the west greatly affects the climate of the Hanford area. Hanford is in the rain shadow of these mountains, which results in relatively low rainfalls over the Hanford site. By serving as a source of cold air drainage the Cascade Mountains also have considerable influence on the wind and temperature regime at Hanford. This drainage (gravity) wind, plus topographic channeling, causes a considerable diurnal range of wind speeds during the summer at the HMS.

The HMS experiences high winds due to squall lines, frontal passages, strong pressure gradients and thunderstorms. This site has experienced only one observed tornado and has not been known to be affected by hurricanes.

Table II.3-E-1 is a summary of local climatological observations, including means and extremes.

II.3-E.2 Temperature

The average maximum temperatures in January and July are 36.7°F and 91.8°F, respectively. The average minimum temperatures for the same months are 22.1°F and 61.0°F, based on local records from 1912 to 1970. The daily temperature range is about 17°F in January and about 30°F in July. Mountain ranges shield the area from many of the arctic air surges and half of all winters are free of temperatures as low as 0°. However, six winters in 58 of record show a total of 16 days with temperatures -20°F or below, and in January-February 1950, there were four consecutive such days. Ten days of record occurred when even the maximum temperature failed to rise above zero. At the other extreme, in the winter of 1925-1926, the lowest temperature all season was +22°.

Although the minimum winter season temperatures have varied from -27° to +22°F, summer season maximum temperatures varied only from 100°F to 115°F. However, considerable variation occurs in the frequency of such maxima. For example, in 1954 there was only one day with a maximum as high as 100°F. On the other hand, in two summers (1938 and 1967) the temperature went to 100°F or above for 11 consecutive days.

Although temperatures reach 90°F or above on an average of 56 days a year, there were only seven annual occurrences of overnight minima 70°F or above. The usual cool nights are a result of the gravity wind. Figure II.3-E-1 presents an annual graphical summary of the diurnal normals and extremes of air temperature.

By applying Gumbel's[2] theory of extreme values, the probability of occurrence of extreme values of highest and lowest temperatures was developed.[3] These findings are presented in Figures II.3-E-2 and II.3-E-3. The figures show the expected frequency of climatological extremes already experienced at Hanford as well as the frequency with which still greater extremes can be expected. Also a period of time can be specified, which may be in centuries, and the magnitude of an extreme can be estimated, which can be expected within that period. The charts employ both normal and extreme probability theory. Because of limitations inherent in any theory which uses a brief history for projecting into the future, the charts should be considered as only "best estimates" based on the available array of data.

TABLE II.3-E-1

AVERAGES AND EXTREMES OF CLIMATIC ELEMENTS AT HANFORD (Based on all available records to and including the year 1970)

TEMPERATURE (°F)

	1912-1970 AVERAGES							1912-1970 EXTREMES							
								DAILY MAXIMUM				DAILY MINIMUM			
	DAILY MAXIMUM	DAILY MINIMUM	MONTHLY	HIGHEST MONTHLY	YEAR	LOWEST MONTHLY	YEAR	RECORD HIGHEST	YEAR	RECORD LOWEST	YEAR	RECORD HIGHEST	YEAR	RECORD LOWEST	YEAR
Jan.	36.7	22.1	29.4	42.5	1953	12.1	1950	66	1968	-2	1950	51	1921	-23	1937+
Feb.	45.3	27.1	36.2	44.5	1958	21.4	1929	71	1924	-3	1950	55	1932	-23	1950
Mar.	56.5	33.8	45.2	49.8	1926	39.4	1955	83	1960	24	1960	54	1942	6	1955
Apr.	66.3	40.1	53.2	59.6	1934	47.5	1955	95	1934	41	1945	60	1956	12	1935
May	75.5	48.0	61.8	68.8	1947	56.6	1933	103	1936+	49	1918	70	1956	28	1954
June	83.2	55.5	69.4	75.4	1922	63.0	1953	110	1912	55	1966	81	1924	33	1933
July	91.8	61.0	76.4	81.8	1960	72.4	1963	115	1939	59	1966	82	1925	41	1935
Aug.	89.2	59.2	74.2	81.5	1967	69.8	1964	113	1961	63	1920	81	1961	40	1918
Sept	79.6	50.8	65.2	71.7	1967	58.8	1926	102	1950	52	1934+	72	1955	25	1926
Oct.	65.3	40.8	53.1	59.0	1952	48.8	1930	90	1933	31	1935	60	1945+	6	1935
Nov.	48.6	31.5	40.0	46.0	1954+	31.3	1955	73	1934	14	1955	52	1959+	-1	1955
Dec.	39.2	26.0	32.6	42.0	1933	18.5	1919	68	1933	-3	1919	53	1933+	27	1919
Year	64.8	41.4	53.1	81.8	July 1960	12.1	Jan. 1950	115	July 1939	-3	Feb 1950+	82	July 1925	-27	Dec 1919

DEGREE DAYS (BASE 65°F) and PRECIPITATION (INCHES)

	DEGREE DAYS 1945-1970 TOTALS					PRECIPITATION 1912-1970 TOTALS							SNOW, ICE PELLETS (SLEET)						
	MEAN MONTHLY	MAXIMUM MONTHLY	YEAR	MINIMUM MONTHLY	YEAR	MEAN MONTHLY	MAXIMUM MONTHLY	YEAR	MINIMUM MONTHLY	YEAR	MAX. IN 24 HOURS	YEAR	MEAN MONTHLY	MAXIMUM MONTHLY	YEAR	MAX. IN 24 HOURS	YEAR	MAXIMUM DEPTH	YEAR
Jan.	1094	1640	1950	694	1953	0.93	2.47	1970	0.13	1962+	1.08	1948	5.2	23.4	1950	7.1	1954	12.0	1969
Feb.	778	1147	1956	576	1958	0.62	3.08	1940	T	1967+	1.24	1916	2.3	26.0	1916	5.2	1959	10.0	1969
Mar.	642	794	1955	476	1947	0.36	1.86	1957	0	1942+	0.59	1949	0.3	4.2	1951	2.2	1957+	2.3	1957
Apr.	381	522	1955	266	1947	0.40	1.22	1969	0	1933+	0.53	1951	T	T	1968+	T	1968+	0	----
May	153	255	1962	36	1947	0.45	1.71	1948	0	1931	0.55	1948+	T	T	1960	T	1960	0	----
June	34	90	1953	3	1958	0.57	2.92	1950	0	1919	1.50	1934	0	0	-	0		0	----
July	3	22	1955	0	1970+	0.14	0.81	1966	0	1939+	0.73	1914	0	0	-	0		0	----
Aug.	5	32	1960	0	1970+	0.19	1.18	1920	0	1955+	0.57	1947	0	0	---	0	---	0	---
Sept	67	122	1970	13	1967	0.30	1.34	1947	T	1961+	0.82	1947	0	0		0	---	0	---
Oct.	373	479	1946	200	1952	0.58	2.72	1957	0	1917+	1.91	1957	T	0.3	1957	0.3	1957	0.3	1957
Nov.	746	1008	1955	567	1954	0.85	3.05	1926	T	1939+	0.78	1966	1.2	12.7	1955	4.8	1955	5.1	1946
Dec.	991	1224	1964	822	1957	0.86	2.53	1931	0.11	1946	1.00	1958	3.7	13.4	1955	5.4	1965	12.1	1964
Year	5267	1640	Jan. 1950	0	Aug. 1970+	6.25	3.08	Feb 1940	0	Aug. 1955+	1.91	Oct. 1957	12.7	26.0	Feb. 1916	7.1	Jan. 1954	12.1	Dec. 1964

WIND (mph)

	1945-1970 AVERAGES						PEAK GUST		
	PREVAILING DIRECTION	MEAN MONTHLY SPEED	HIGHEST MONTHLY	YEAR	LOWEST MONTHLY	YEAR	SPEED	DIRECTION	YEAR
Jan	NW	6.3	9.6	1953	3.1	1955	65	S	1967
Feb.	NW	7.0	9.4	1961	4.6	1963	63	SW	1965
Mar.	WNW	8.4	10.7	1964	5.9	1958	70	SW	1956
Apr.	WNW	9.0	11.1	1959	7.4	1958	60	WSW	1969
May	WNW	8.8	10.5	1965+	5.8	1957	71	SSW	1948
June	WNW	9.2	10.7	1949	7.7	1950+	72	SW	1957
July	WNW	8.6	9.6	1963	6.8	1955	55	WSW	1968
Aug.	WNW	8.0	9.1	1946	6.0	1956	66	SW	1961
Sept.	WNW	7.5	9.2	1961	5.4	1957	65	SSW	1953
Oct.	WNW	6.7	9.1	1946	4.4	1952	63	SSW	1950
Nov.	NW	6.2	7.9	1945	2.9	1956	64	SSW	1949
Dec.	NW	6.0	8.3	1968	3.9	1963+	71	SW	1955
Year	WNW	7.6	11.1	Apr. 1959	2.9	Nov. 1956	72	SW	June 1957

RELATIVE HUMIDITY (%) and SKY COVER (SCALE 0-10)

	RELATIVE HUMIDITY 1946-1970 AVERAGES					RELATIVE HUMIDITY 1946-1970 EXTREMES				SKY COVER 1946-1970 AVERAGES (SUNRISE TO SUNSET)				
	MEAN	HIGHEST MONTHLY	YEAR	LOWEST MONTHLY	YEAR	HIGHEST	YEAR	LOWEST	YEAR	MONTHLY	HIGHEST MONTHLY	YEAR	LOWEST MONTHLY	YEAR
Jan	75.7	88.8	1960	60.0	1963	100	1970+	13	1963	7.8	9.0	1969	4.3	1949
Feb.	69.9	86.9	1963	54.0	1967	100	1970+	14	1962	7.4	8.9	1961	5.9	1964
Mar.	55.8	65.9	1950	44.0	1965	100	1970+	12	1965+	6.7	7.9	1950	4.9	1965
Apr.	46.7	64.5	1963	36.9	1966	100	1963+	9	1954	6.4	8.1	1963	3.7	1951
May	42.2	62.4	1948	31.2	1966	100	1969+	7	1953	5.8	7.7	1960	4.5	1949
June	39.6	53.5	1950	30.0	1949	100	1967+	10	1964+	5.2	7.0	1950	2.8	1961
July	31.8	40.5	1955	21.9	1959	97	1963	6	1951	2.7	4.5	1955	0.9	1953
Aug.	34.8	43.8	1968	24.5	1967	100	1959	7	1951	3.3	5.9	1968	0.6	1955
Sept.	40.6	55.1	1959	33.9	1952	100	1962+	10	1962+	4.1	6.1	1959	2.5	1950
Oct.	57.8	74.2	1962	42.5	1952	100	1969+	10	1952	5.9	7.7	1950	3.9	1952
Nov.	72.9	80.5	1956	64.1	1959	100	1970+	16	1959	7.5	9.0	1965	6.2	1957
Dec.	80.4	89.9	1963	69.0	1968	100	1970+	28	1968+	8.1	9.2	1962	6.8	1954
Year	54.0	89.9	Dec. 1963	21.9	July 1959	100	Dec. 1970+	6	July 1951	5.9	9.2	Dec. 1962	0.6	Aug 1955

SOLAR RADIATION (LANGLEYS) (a)

	1953-1970 AVG DAILY TOTALS					1953-1970 EXTREME DAILY TOTALS			
	MONTHLY	HIGHEST MONTHLY	YEAR	LOWEST MONTHLY	YEAR	HIGHEST MONTHLY	YEAR	LOWEST MONTHLY	YEAR
Jan	118	135	1962	88	1955	277	1969	16	1970
Feb.	200	236	1960	164	1954	422	1958	37	1970+
Mar.	340	388	1965	305	1961	542	1968	71	1963
Apr.	470	526	1959+	374	1963	691	1958	115	1970
May	571	634	1970	511	1962	782	1959	67	1962
June	626	698	1960	563	1953	809	1957	112	1965
July	659	700	1969+	588	1955	789	1969	150	1955
Aug.	551	613	1955	475	1968	721	1957	107	1959
Sept.	418	457	1961	354	1959	591	1970	61	1957
Oct.	262	299	1958	227	1956	428	1958	58	1962
Nov.	135	180	1957	97	1964	283	1957	14	1969
Dec.	91	116	1970	57	1969	185	1960	14	1969+
Year	370	700	July 1969+	57	Dec 1969	809	June 1957	14	Dec. 1969+

EXTREME AVERAGES OR TOTALS AND YEAR OR SEASON OF OCCURENCE

1912-1970 TEMPERATURE AVERAGES (°F)		
HIGHEST ANNUAL	56.2	1958+
LOWEST ANNUAL	50.2	1929
HIGHEST WINTER (D-J-F)	41.1	1933-34
LOWEST WINTER	24.2	1948-49
HIGHEST SPRING (M-A-M)	58.2	1947
LOWEST SPRING	48.0	1955
HIGHEST SUMMER (J-J-A)	78.2	1958
LOWEST SUMMER	70.3	1954
HIGHEST FALL (S-O-N)	56.6	1963
LOWEST FALL	49.6	1946
1912-1970 PRECIPITATION TOTALS (IN.)		
GREATEST ANNUAL	*11.45	1950
LEAST ANNUAL	3.26	1967
SNOW, ICE PELLETS (SLEET) GREATEST SEASONAL	43.6	1915-16
LEAST SEASONAL	0.3	1957-58
1945-1970 WIND SPEED AVERAGE (mph)		
HIGHEST ANNUAL	8.3	1968+
LOWEST ANNUAL	6.3	1957
1946-1970 RELATIVE HUMIDITY AVERAGE (%)		
HIGHEST ANNUAL	57.9	1950+
LOWEST ANNUAL	49.4	1967
1946-1970 SKY COVER AVERAGES (SUNRISE TO SUNSET, SCALE 0-10)		
HIGHEST ANNUAL	6.4	1966
LOWEST ANNUAL	5.1	1949
1953-1970 SOLAR RADIATION AVERAGE DAILY TOTAL (LANGLEYS)		
HIGHEST ANNUAL	385	1957
LOWEST ANNUAL	357	1967

TABLE II.3-E-1 (Continued)

NUMBER OF DAYS (1945 1970) (b)

	CLEAR					PTLY CLDY	CLOUDY				
	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	YEAR	MEAN	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	YEAR
Jan.	4	13	1949	0	1955+	7	20	27	1969+	6	1949
Feb	5	9	1968+	1	1969+	6	17	26	1958	10	1951+
Mar.	7	12	1965+	2	1961+	9	15	22	1968	7	1948
Apr.	7	18	1951	1	1963	11	12	21	1963	3	1949
May	8	14	1953	2	1960	12	11	19	1960	3	1949
June	11	21	1961	3	1966	10	9	15	1957	0	1949
July	21	27	1953	14	1955	7	3	8	1955	0	1967+
Aug	19	30	1955	11	1968	8	4	13	1968	0	1969+
Sept.	15	21	1967	8	1969	8	7	13	1969	2	1952+
Oct.	10	16	1953	3	1950+	9	12	18	1956+	3	1946
Nov.	5	10	1957	1	1965+	6	19	24	1965+	12	1948
Dec.	3	7	1954	0	1947	7	21	28	1962	14	1946
Year	115	30	Aug. 1955	0	Jan. 1955+	100	150	28	Dec. 1962	0	Aug 1969+

	THUNDERSTORMS					HEAVY FOG (VIS 1/4 MI OR LESS)				
	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	YEAR	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	YEAR
Jan.	0	0	-	0	---	6	14	1965	0	1949
Feb	#	1	1962	0	1970+	3	11	1963	0	1967+
Mar.	#	1	1969+	0	1970+	#	5	1951	0	1968+
Apr.	1	3	1948	0	1970+	#	1	1950	0	1970+
May	2	7	1956	0	1965+	#	1	1958	0	1970+
June	3	8	1948	0	1963+	0	0	--	0	-
July	2	5	1958+	0	1969+	0	0	---	0	---
Aug	2	8	1953	0	1969+	#	1	1959	0	1970+
Sept.	1	4	1959	0	1970+	#	1	1957	0	1970+
Oct.	#	1	1968+	0	1970+	1	6	1962	0	1970+
Nov.	0	0	----	0	---	5	13	1965	0	1960
Dec.	0	0	--	0	--	6	17	1950	2	1968+
Year	11	8	Aug 1953+	0	----	24	17	Dec. 1950	0	----

	PRECIP. 0.10 INCH OR MORE					SNOW 1.0 INCH OR MORE				
	MEAN	GREATEST MONTHLY	YEAR	LEAST MONTHLY	YEAR	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	YEAR
Jan.	3	8	1970	0	1962+	2	10	1950	0	1967+
Feb	2	5	1961+	0	1967+	1	4	1959+	0	1970+
Mar.	2	8	1957	0	1968+	#	2	1957+	0	1970+
Apr.	2	5	1948	0	1968+	0	0	----	0	----
May	2	4	1967+	0	1968+	0	0	----	0	----
June	2	8	1950	0	1962+	0	0	----	0	----
July	1	3	1955	0	1970+	0	0	----	0	----
Aug	1	3	1953	0	1970+	0	0	----	0	----
Sept.	1	5	1959	0	1970+	0	0	----	0	----
Oct.	2	8	1950	0	1969+	0	0	----	0	----
Nov.	3	7	1966+	0	1967	#	6	1955	0	1970+
Dec.	3	9	1964	0	1949+	2	6	1964	0	1966+
Year	24	9	Dec. 1964	0	Sept. 1970+	5	10	Jan. 1950	0	----

NUMBER OF DAYS (1945-1970)

	3" OR MORE SNOW ON GND.					PEAK GUST 40 MPH OR GREATER				
	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	YEAR	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	YEAR
Jan.	5	23	1969	0	1967+	3	9	1953	0	1957+
Feb.	3	16	1950	0	1970+	2	6	1961+	0	1970+
Mar.	0	0	----	0	----	3	9	1956	1	1965+
Apr.	0	0	----	0	----	3	6	1959	0	1967+
May	0	0	----	0	----	2	6	1951	0	1963+
June	0	0	----	0	----	2	4	1970+	0	1967+
July	0	0	----	0	----	1	4	1962+	0	1969+
Aug.	0	0	----	0	----	1	5	1951	0	1970+
Sept.	0	0	----	0	----	2	4	1951	0	1970+
Oct.	0	0	----	0	----	2	8	1967	0	1957+
Nov.	1	10	1955	0	1970+	2	5	1961+	0	1969+
Dec.	2	14	1955	0	1969+	3	8	1957+	0	1969+
Year	11	23	Jan. 1969	0	----	26	9	Jan. 1953	0	----

NUMBER OF DAYS (1912-1970)

	MAX. TEMP. 90 OR ABOVE					MAX. TEMP. 100 OR ABOVE				
	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	YEAR	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	YEAR
Jan.	0	0	----	0	----	0	0	----	0	----
Feb.	0	0	----	0	----	0	0	----	0	----
Mar.	0	0	----	0	----	0	0	----	0	----
Apr.	#	4	1926	0	1970+	0	0	----	0	----
May	3	11	1924	0	1965+	#	1	1966+	0	1970+
June	9	20	1940+	0	1953	2	9	1970	0	1968+
July	21	29	1941	8	1963	7	16	1960+	0	1963+
Aug.	18	29	1915	7	1948	4	16	1942	0	1964+
Sept.	5	16	1938	0	1970+	#	2	1955+	0	1970+
Oct.	#	1	1933	0	1970+	0	0	----	0	----
Nov.	0	0	----	0	----	0	0	----	0	----
Dec.	0	0	----	0	----	0	0	----	0	----
Year	56	29	July 1941+	0	----	13	16	July 1960+	0	----

	MAX. TEMP. 32 OR BELOW					MIN. TEMP. 32 OR BELOW					MIN. TEMP. 0 OR BELOW				
	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	YEAR	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	YEAR	MEAN MONTHLY	GREATEST MONTHLY	YEAR	LEAST MONTHLY	YEAR
Jan.	11	29	1937	0	1967+	28	31	1960+	9	1953	2	14	1950	0	1970+
Feb.	3	19	1936	0	1970+	22	28	1944+	5	1958	1	9	1929	0	1970+
Mar.	#	2	1960	0	1970+	16	25	1944+	6	1968+	0	0	----	0	----
Apr.	0	0	----	0	----	5	15	1935	0	1962+	0	0	----	0	----
May	0	0	----	0	----	#	3	1938	0	1969+	0	0	----	0	----
June	0	0	----	0	----	0	0	----	0	----	0	0	----	0	----
July	0	0	----	0	----	0	0	----	0	----	0	0	----	0	----
Aug.	0	0	----	0	----	0	0	----	0	----	0	0	----	0	----
Sept.	0	0	----	0	----	#	4	1933+	0	1970+	0	0	----	0	----
Oct.	#	2	1935	0	1970+	5	12	1916	0	1962+	0	0	----	0	----
Nov.	2	15	1955	0	1968+	17	30	1936	4	1949	#	1	1955+	0	1970+
Dec.	8	19	1914	2	1966+	26	31	1963+	14	1933	1	14	1919	0	1970+
Year	24	29	Jan. 1937	0	----	119	31	Dec. 1963+	0	----	4	14	Jan. 1950+	0	----

NUMBER OF DAYS

CLEAR (0-3 TENTHS SKY COVER, SR TO SS)
- GREATEST ANNUAL (1946-70) 141 1951
- LEAST ANNUAL (1946-70) 85 1966

CLOUDY (8-10 TENTHS SKY COVER, SR TO SS)
- GREATEST ANNUAL (1946-70) 182 1969+
- LEAST ANNUAL (1946-70) 84 1949

THUNDERSTORMS
- GREATEST ANNUAL (1945-70) 23 1948
- LEAST ANNUAL (1945-70) 3 1949

HEAVY FOG (VIS. 1/4 MILE OR LESS)
- GREATEST SEASONAL (1945-70) 42 1950-51
- LEAST SEASONAL (1945-70) 9 1948-49

PRECIPITATION 0.10 INCH OR MORE
- GREATEST ANNUAL (1946-70) 39 1950
- LEAST ANNUAL (1946-70) 10 1965

SNOW 1.0 INCH OR MORE
- GREATEST SEASONAL (1946-70) 15 1955-56
- LEAST SEASONAL (1946-70) 0 1957-58

3 IN. OR MORE SNOW ON GROUND
- GREATEST SEASONAL (1946-70) 40 1964-65
- LEAST SEASONAL (1946-70) 0 1960-61+

PEAK GUST 40 MPH OR GREATER
- GREATEST ANNUAL (1945-70) 41 1961
- LEAST ANNUAL (1945-70) 13 1958

MAX. TEMPERATURE 90 OR ABOVE
- GREATEST ANNUAL (1912-70) 85 1940+
- LEAST ANNUAL (1912-70) 37 1954

MAX. TEMPERATURE 100 OR ABOVE
- GREATEST ANNUAL (1912-70) 32 1942
- LEAST ANNUAL (1912-70) 1 1954

MAX. TEMPERATURE 32 OR BELOW
- GREATEST SEASONAL (1912-70) 53 1955-56
- LEAST SEASONAL (1912-70) 1 1937-38

MIN. TEMPERATURE 32 OR BELOW
- GREATEST SEASONAL (1912-70) 141 1916-17
- LEAST SEASONAL (1912-70) 75 1957-58

MIN. TEMPERATURE 0 OR BELOW
- GREATEST SEASONAL (1912-70) 18 1949-50
- LEAST SEASONAL (1912-70) 0 1969-70+

REFERENCE NOTES

(a) CALORIES/cm^2

(b) SKY COVER AND PRECIPITATION OBSERVATIONS NOT BEGUN UNTIL 1946

\# LESS THAN 1/2

\+ ALSO ON EARLIER YEARS

LOCATION AND HISTORY

PRESENT LOCATION 25 MILES NW OF RICHLAND, WASHINGTON

LATITUDE 46°34' N; LONGITUDE 119°36' W ELEVATION 733 FEET

OBSERVATIONS FROM 1912 TO 1944 WERE BY UNITED STATES WEATHER BUREAU COOPERATIVE OBSERVERS AT A SITE ABOUT 10 MILES ENE OF PRESENT LOCATION. SINCE 1944 OBSERVATIONS HAVE BEEN MAINTAINED ON A 24 HOUR-A-DAY BASIS BY THREE DIFFERENT CONTRACTORS.

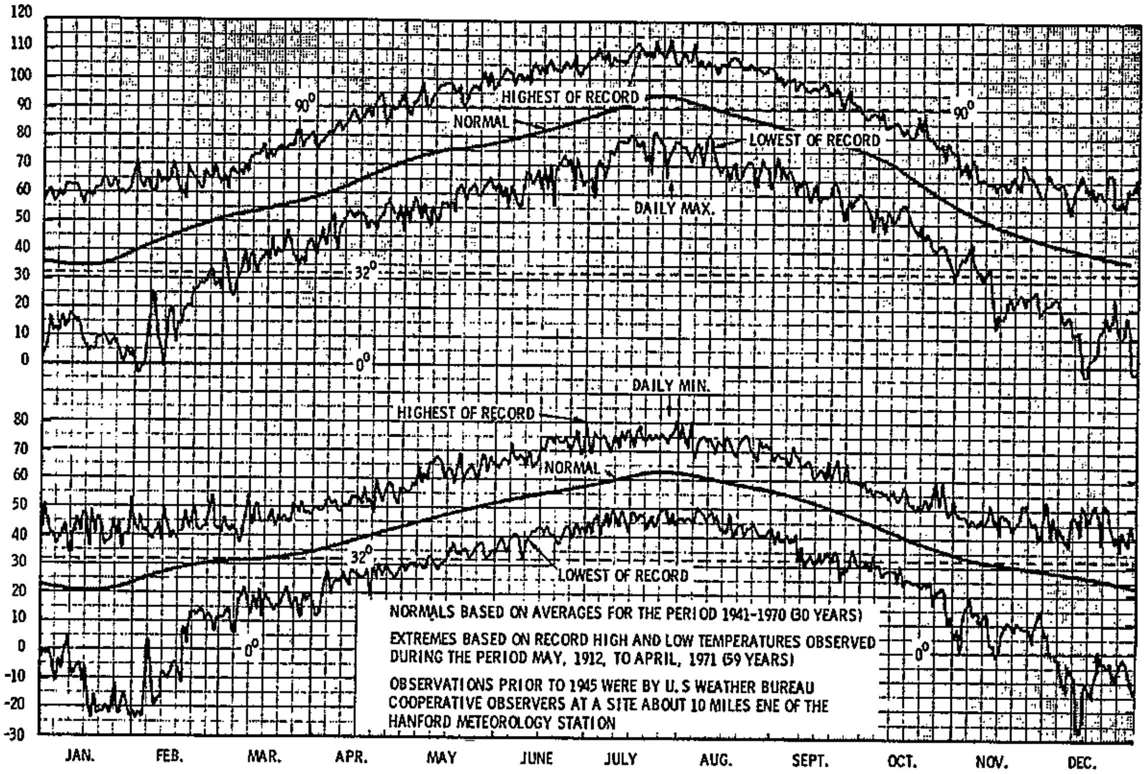

FIGURE II.3-E-1 ANNUAL VARIATION OF NORMAL AND EXTREME DAILY MAXIMUM AND MINIMUM TEMPERATURES AT HMS

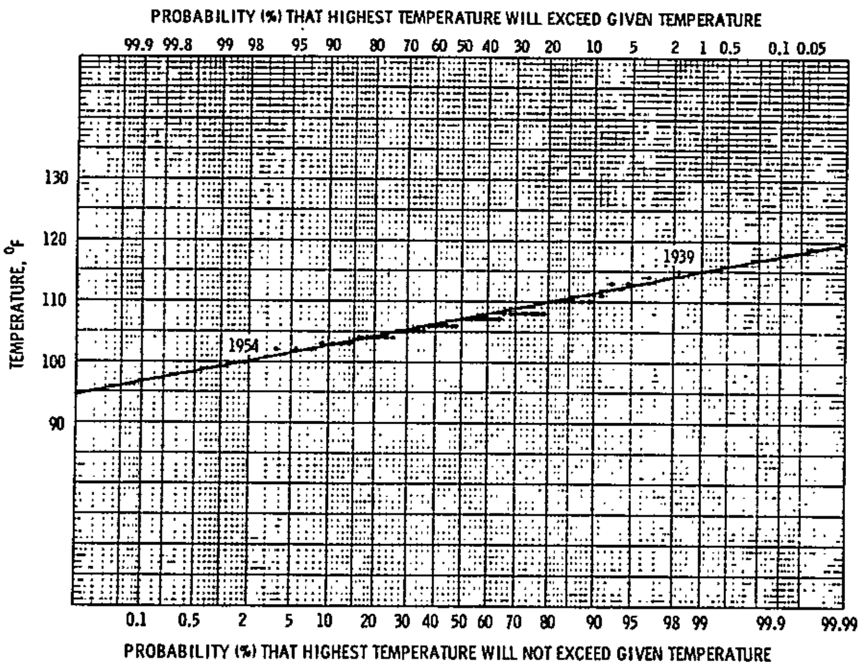

FIGURE II.3-E-2 PROBABILITIES OF HIGH TEMPERATURES BASED ON THE HIGH TEMPERATURE DURING EACH OF 57 SUMMERS OF RECORD AT HANFORD: 1912-1969

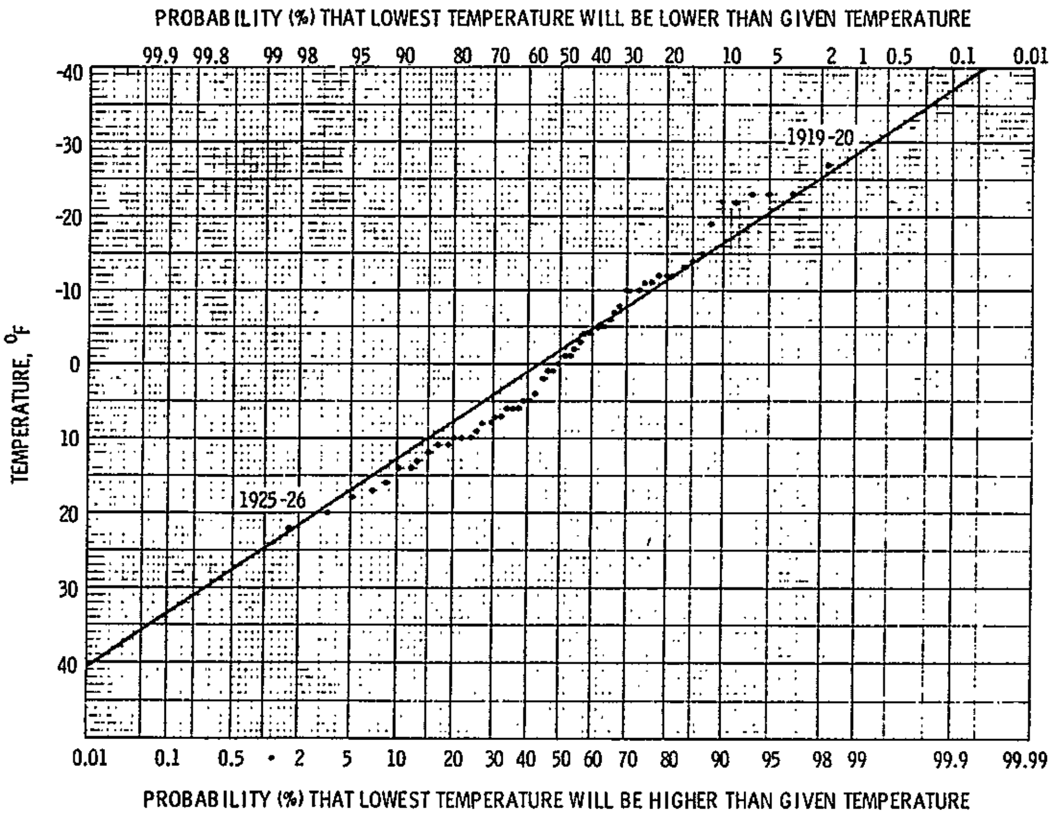

FIGURE II.3-E-3 PROBABILITY OF LOW TEMPERATURES BASED ON LOWEST TEMPERATURE DURING EACH OF 58 WINTERS AT HANFORD: 1912-13 to 1969-70

A "chinook"[4] is defined as a warm and dry west wind of the foëhn type which occurs on the eastern side of the Rocky Mountains. Its arrival is usually sudden, with a consequent large temperature rise and rapid melting snow. During the winter months the Hanford area frequently experiences the "chinook inversion." For example, on January 7, 1949, the temperature rose from 19° to 43° (24°) in one hour as the result of the passage of a warm front (Figure II.3-E-4). On November 24, 1970, the temperature rose 8° in 4 minutes, 15° within 15 minutes, and 22° within 30 minutes. In all, the temperature on November 24, 1970, rose from a morning low of 24° to a high of 60°. The high of the previous day was 25°.

Temperature records have been summarized for limited periods of time at various locations on the Hanford Reservation including the Wahluke Slope Station (6 year summary),[1] the Hanford Steam Generating Plant Area (1 year summary)[6] and the Arid Lands Ecology Reserve.[7]

Climatologically speaking, no apparent significant temperature differences occur among the low-level sites although simultaneous temperature differences between low-level sites on the order of 10 to 15 degrees have frequently been observed. The pattern of weekly and monthly maximum temperatures over the Arid Lands Ecology (ALE) Reserve presents essentially a uniform adiabatic lapse rate of temperature with increasing elevation. Local topography modifies this pattern, especially near the crest of the Rattlesnake Hills. Isotherms of minimum temperature indicate a well defined nocturnal temperature inversion reaching from 600 to 1000 feet above the valley floor. The intensity of the inversion appears to be dependent on season; months near September and March exhibit minimum temperatures near the top of the inversion 10 to 15°F warmer than those of the valley floor, whereas near June and December the difference is more nearly 5 to 10°F.

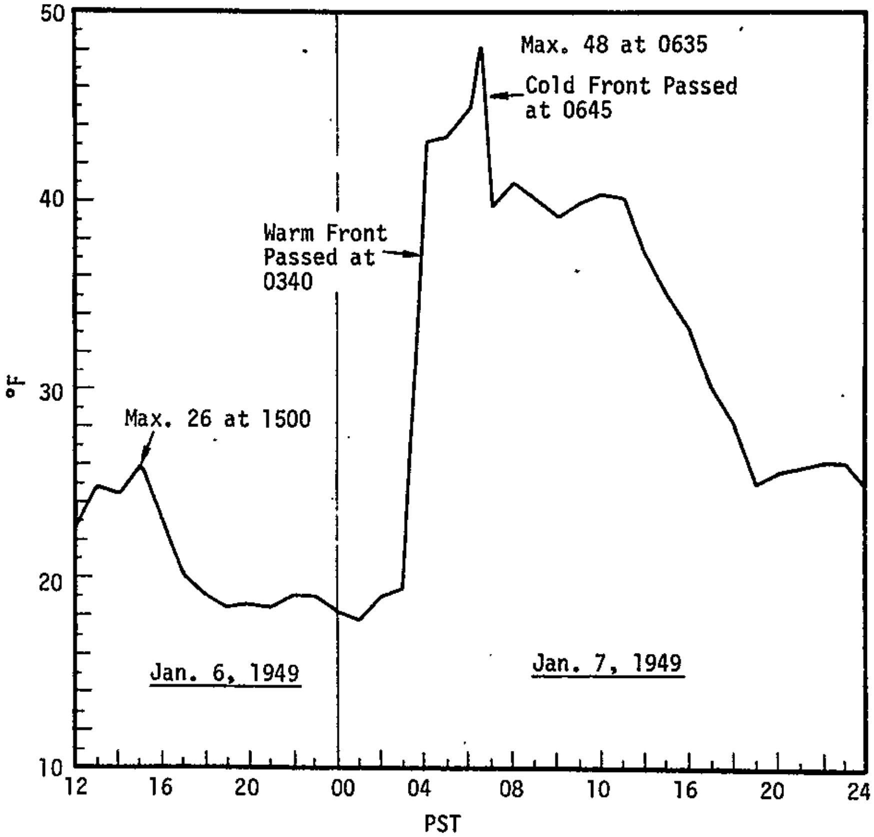

FIGURE II.3-E-4 EXAMPLE OF EFFECT OF CHINOOK (Observed hourly temperatures at Hanford, January 6-7, 1949)

II.3-E.3 Humidity

Relative humidity averages 75.7% and 31.8% in January and July, respectively, based on 15 recent years of record. The highest monthly average relative humidity was 89.9% in December 1963, and the lowest average was 21.9% in July 1959. Figure II.3-E-5 presents January, July and annual hourly averages of dry bulb and wet bulb temperature values at HMS. Table II.3-E-2 presents monthly and annual frequency of occurrence of wet bulb temperature values at HMS. The other location on Hanford for which such information is available is at the WNP-2 site, elevation 450 feet MSL, about 15 miles ESE of the HMS and within four miles of the Columbia River. A summary of the frequency of occurrence of wet bulb values by months for one year of data is given in Table II.3-E-3.

Relatively higher humidity values can be expected at locations near the Columbia River as the result of the increased availability of airborne water vapor evaporating from the river. Relative humidity values on the Wahluke Slope portion of the Hanford Reservation can be significantly higher as a result of agricultural irrigation operations conducted there. Relative humidity values can be expected to rise as one approaches the periphery of the Hanford area, again due to increased proximity to extensive agricultural irrigation operations.

Although the Southern Columbia Basin Irrigation District surrounding the Hanford area has increased to about 180,700 hectares during the past 23 years,[8] no apparent increase in atmospheric moisture in terms of relative humidity has been detected at the HMS near the middle of the Hanford Reservation. Figure II.3-E-6 presents mean values of relative humidity for July as well as long-term running means.

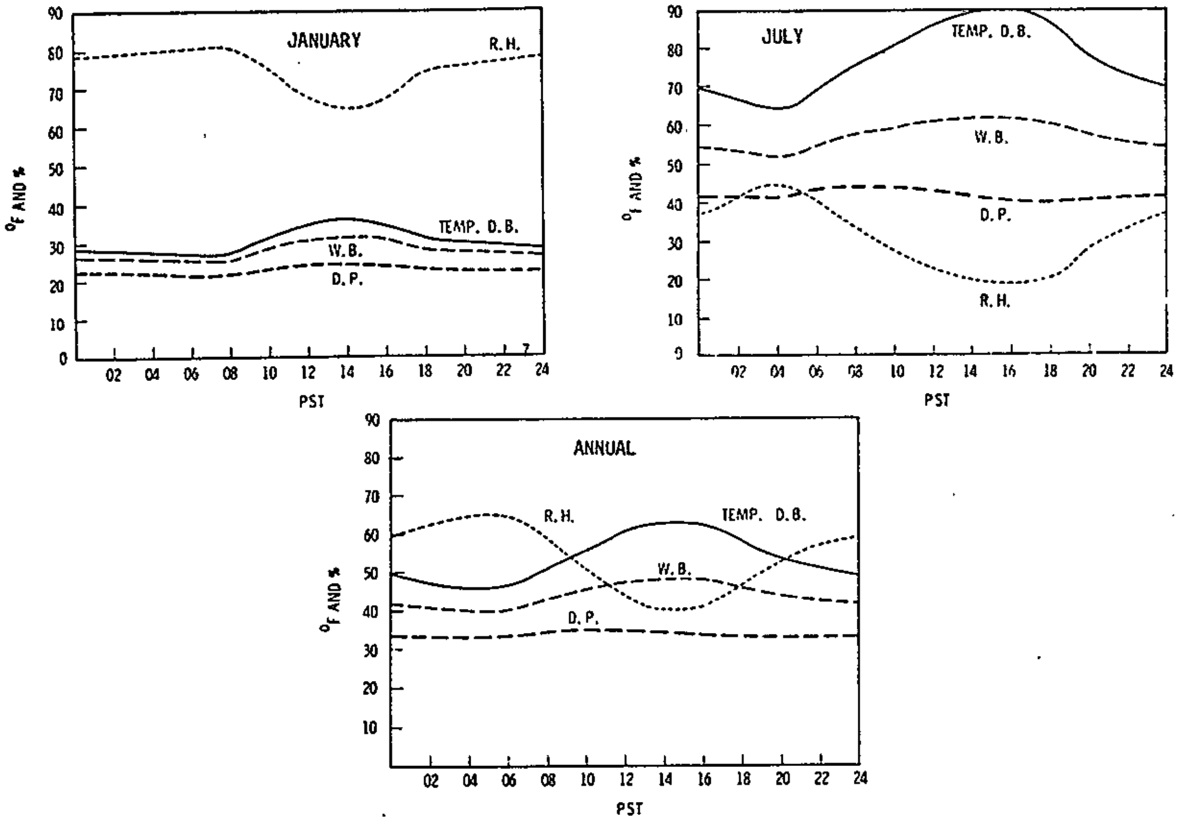

FIGURE II.3-E-5 JANUARY, JULY, AND HOURLY AVERAGES OF DRY BULB (D.B.) AND WET BULB (W.B.) TEMPERATURE, RELATIVE HUMIDITY (R.H.) AND DEW POINT TEMPERATURE (D.P.) AT HMS, 1957-1970

TABLE II.3-E-2

MONTHLY AND ANNUAL FREQUENCY OF OCCURRENCE (%) OF WET BULB VALUES (°F)
PERIOD OF RECORD AT HMS, 1957-70 (TOTAL OBSERVATIONS: 122,712)

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	ANNUAL
75-79	0	0	0	0	0	0	0	0	0	0	0	0	0
70-74	0	0	0	0	0	0.06	0.38	0.14	0	0	0	0	0.05
65-69	0	0	0	0	0.64	4.61	10.72	7.90	1.46	0	0	0	2.13
60-64	0	0	0	0.30	4.59	17.85	30.44	27.50	12.32	0.94	0	0	7.89
55-59	0.05	0.01	0.30	2.39	16.10	30.74	32.18	35.01	26.21	7.94	0.16	0	12.66
50-54	0.48	1.30	2.90	10.60	28.32	30.13	20.34	22.02	31.29	17.07	2.47	0.21	13.97
45-49	2.15	6.00	12.59	26.40	27.14	13.82	5.22	6.62	18.71	29.19	11.68	7.28	13.50
40-44	8.30	18.41	27.31	32.80	16.68	2.65	0.69	0.75	7.54	25.89	23.91	9.57	14.49
35-39	15.77	26.62	28.24	19.85	5.39	0.14	0	0.05	1.85	12.93	25.33	20.96	13.00
30-34	23.60	26.24	16.86	6.55	1.08	0	0	0	0.62	5.19	19.87	30.69	10.82
25-29	20.60	13.69	8.69	1.07	0.07	0	0	0	0.01	0.74	10.58	19.57	6.23
20-24	11.41	4.66	1.99	0.05	0	0	0	0	0	0.11	3.93	9.72	2.66
15-19	7.03	1.50	0.88	0	0	0	0	0	0	0	1.64	3.47	1.22
10-14	4.23	1.26	0.25	0	0	0	0	0	0	0	0.34	1.64	0.64
05-09	3.21	0.23	0	0	0	0	0	0	0	0	0.11	0.53	0.34
00-04	1.71	0.05	0	0	0	0	0	0	0	0	0	0.44	0.19
-05/-01	0.82	0.02	0	0	0	0	0	0	0	0	0	0.41	0.11
-10/-06	0.32	0	0	0	0	0	0	0	0	0	0	0.37	0.06
-15/-11	0.16	0	0	0	0	0	0	0	0	0	0	0.13	0.03
-20/-16	0.13	0	0	0	0	0	0	0	0	0	0	0	0.01
L.T. -20	0.03	0	0	0	0	0	0	0	0	0	0	0	0

TABLE II.3-E-3

WNP-2 SITE MONTHLY AND ANNUAL FREQUENCY OF OCCURRENCE (%) OF WET BULB VALUES

	1972				1973								
	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Annual
AB 79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
75-79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.27	0.06
70-74	1.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.64	14.38	10.35	2.37
65-69	6.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.81	10.28	21.24	19.22	4.82
60-64	8.19	0.40	0.00	0.00	0.00	0.00	0.00	0.00	7.39	16.94	24.73	23.25	6.74
55-59	17.22	5.24	0.00	0.00	0.00	0.00	0.00	1.11	15.32	24.17	21.64	24.33	9.09
50-54	25.14	12.63	1.11	0.81	0.00	0.15	0.54	10.97	21.10	22.78	11.83	13.71	10.06
UN 50	39.17	81.72	98.89	97.04	100.00	99.85	99.46	87.92	55.38	21.67	5.78	8.87	66.31

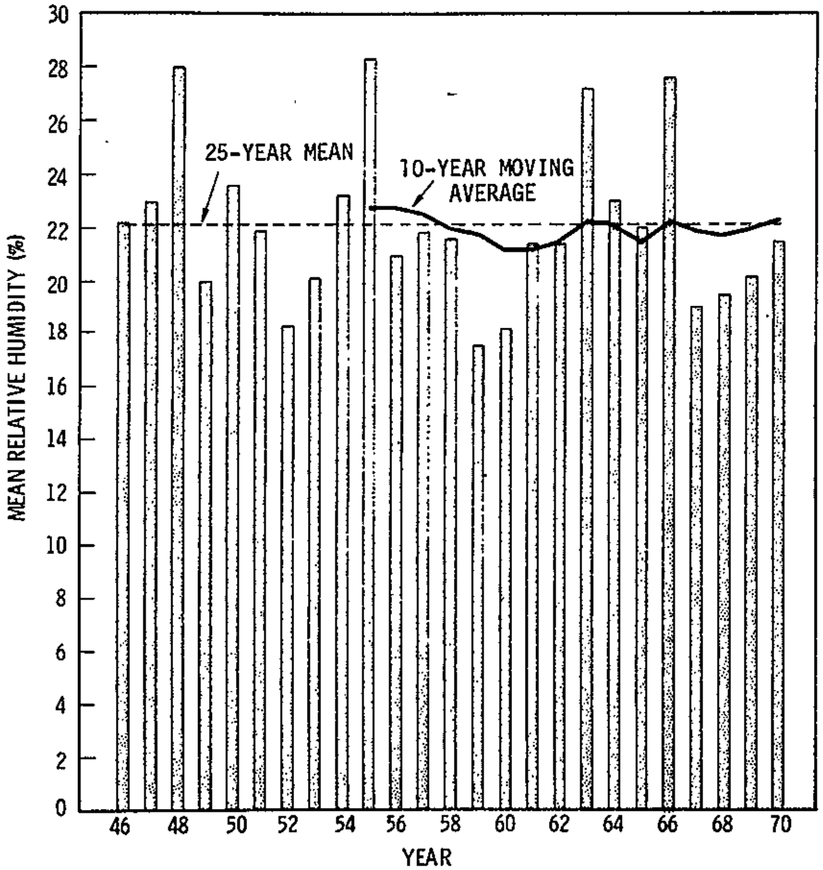

FIGURE II.3-E-6 HMS MEAN RELATIVE HUMIDITY (%) AT 1300 PST IN JULY, EACH YEAR FROM 1946 to 1970

II.3-E.4 Wind

In July, hourly average speeds range from a low of 5.2 mph from 9:00 to 10:00 a.m. to a high of 13.0 mph from 9:00 to 10:00 p.m. In contrast, the corresponding speeds for January are 5.5 and 6.3 mph.

Although the gravity wind occurs with regularity in summer at the HMS, it is never strong unless reinforced by frontal activity. In June, the month of highest average speed, there are fewer instances of hourly averages exceeding 31 mph than in December, the month of lowest average speed. Although channeling results in a prevailing WNW or northwest wind the year round, at the HMS the strongest speeds are from the southwest direction.

Periods of relatively low wind speed are also part of Hanford's wind regime. For example, December has an average of ten days with a peak gust under 13 mph. By contrast, only once in seven years does June have even one such day.

Joint wind speed, direction, and stability data are available from two locations on site. The longest periods of data are from the Hanford Meteorological Station tower. Wind roses for each stability and for all stabilities combined based on 15 years of HMS data are given in Figure II.3-E-7. Included in these are groupings of the persistences by wind speeds for each direction, based on the annual joint distributions of stability (ΔT between the surface and 200 feet), wind speed (200 feet), and direction (200 feet) for the period 1955 through 1970.[1] These data are presented in Table II.3-E-4. Figure II.3-E-8 presents wind rose summaries based on one year of data[6] from the meteorological tower at the N Reactor site. These two locations cover the winds in the northern and central sections of the Hanford site. The definition of stability used in Figures II.3-E-7 and II.3-E-8, as well as in the Hanford diffusion model, is given in Table II.3-E-5.

Wind data are also available for the WNP-2 site about 15 miles ESE of the HMS at an elevation of 450 feet MSL. Figure II.3-E-9 presents wind roses at the WNP-2 site for a 12-month period. Figure II.3-E-10 presents similar data for the HMS site for the same period. Figure II.3-E-11 presents average monthly wind roses for the HMS site over a 15-year period. A comparison of the 12-month HMS data with the 15-year HMS data indicates that winds during the short term were reasonably typical of distributions during the long term. Therefore a reasonable inference is that the WNP-2 short-term winds are also typical of the long term; likewise, apparent differences between the two sites indicated by the two short-term periods of record are probably authentic differences. The most outstanding difference appears to be the much more frequent occurrence of west and northwest wind directions at the HMS site. This can be attributed to the gravity of "drainage" wind which occurs regularly at the HMS during the nocturnal hours but not at the WNP-2 site.

Surface wind rose data based on an eight point compass have been compiled from the telemetering network of meteorological stations. A summary of these wind roses plotted on a map of the measurement site is given in Figure II.3-E-12. These sensors were located so that they would define local topographical effects on surface winds as well as the general surface flow of winds. The occurrence of the gravity or "drainage" wind can be seen at stations 1, 8, 12, 13, and 14. The high occurrence of winds along a southwest-northeast axis at Station 10 can be attributed to a local channeling by topography. At Station 15 again the high occurrence of southwest winds is due to local channeling. At Station 9 the northwest-southeast effect is due to channeling.

As material is transported and dispersed by the atmosphere, a portion of it may be carried or diffused to heights well above the surface boundary layer. For this reason, climatological information on the winds above the surface based sensors is valuable. The seasonal and annual wind rose plots for four levels up to 1500 m are shown in Figure II.3-E-13. The 15 m level wind roses were derived from the once daily observation taken at 1300 PST from the 15 m level on the Hanford tower. The other levels are based on pibal data for a period of 11 years derived from monthly summaries of wind direction and average speed for the 1300 PST observation. For comparison purposes, Figure II.3-E-14 shows the wind roses from this level for the observations taken at 0100 PST, 1300 PST and the composite for all 24 hours.

The wind rose data in Figure II.3-E-14 show a very strong diurnal influence in the winds measured at 15 meters at the HMS. The high percentage of west through northwest winds observed during the early morning hours probably reflects the night time drainage from the higher ground in that direction. This feature does not occur in the afternoon wind rose. The wind roses for the lower levels cannot be considered representative of all hours because of the topographically induced diurnal cycle in the winds. However, the influence of this drainage cycle on the flow diminishes with height and in the Hanford area should have practically no effect above 500 m.

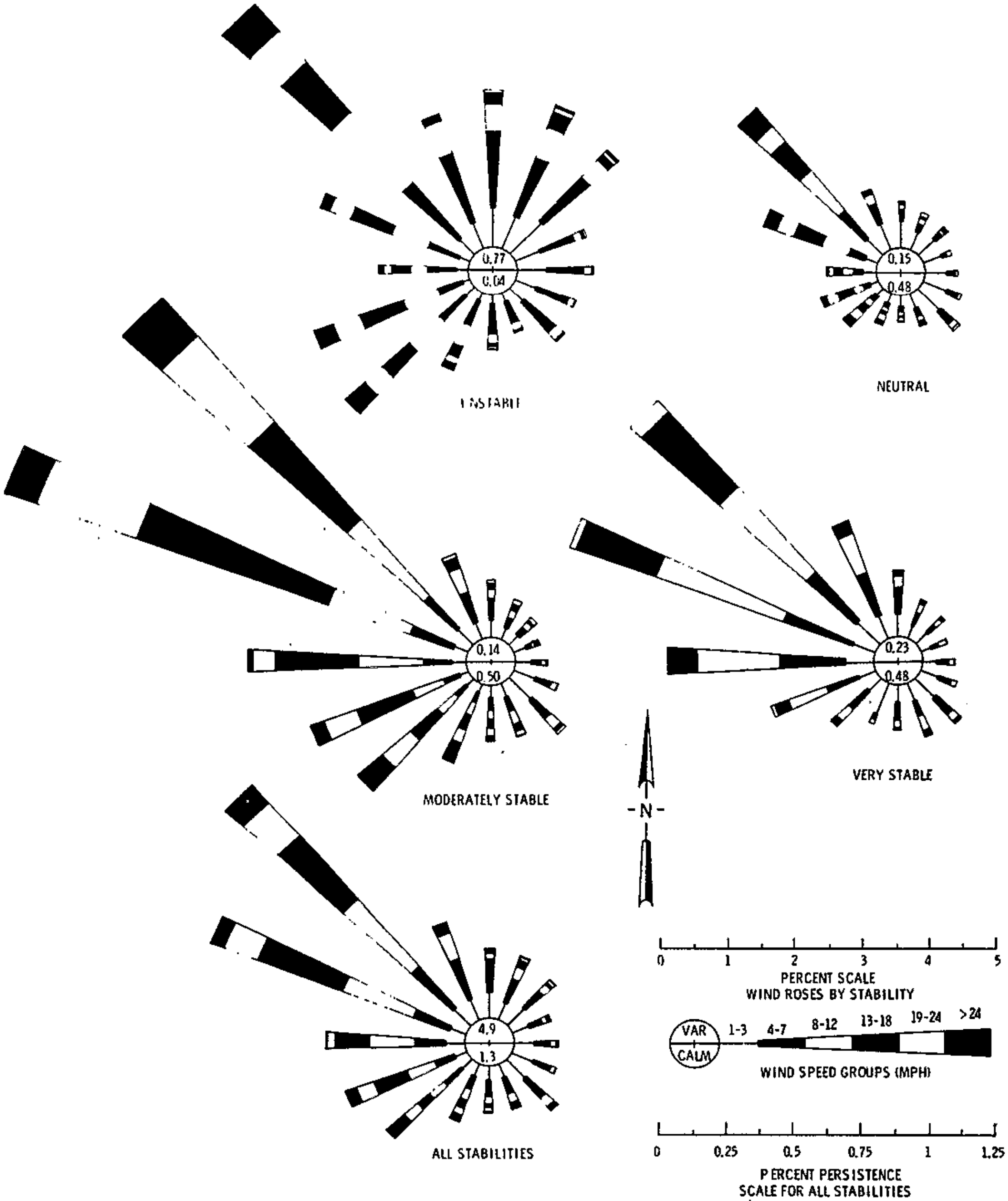

FIGURE II.3-E-7 WIND ROSES AS A FUNCTION OF STABILITY AND FOR ALL STABILITIES OF HMS BASED ON WINDS AT 200 FT AND AIR TEMPERATURE STABILITIES BETWEEN 3 FT AND 200 FT FOR THE PERIOD 1955 THROUGH 1970 (the points of the rose represent the directions from which the winds come)

TABLE II.3-E-4

HMS COMPOSITE REPORT (1955 THROUGH 1970) OF PERCENTAGE FREQUENCY DISTRIBUTION OF WIND SPEED AND WIND DIRECTION AT 200-FT LEVEL VERSUS ATMOSPHERIC STABILITY

(see text for stability definition)

SEASON - SPRING

		NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	VAR.	CALM	TOTAL
0 - 3	VS	0.15	0.13	0.09	0.14	0.21	0.23	0.16	0.13	0.14	0.21	0.15	0.38	0.27	0.31	0.27	0.22	0.14	0.23	3.55
	MS	0.08	0.11	0.08	0.10	0.17	0.20	0.07	0.08	0.08	0.08	0.07	0.14	0.09	0.10	0.14	0.12	0.08	0.08	1.86
	N	0.10	0.20	0.11	0.14	0.20	0.19	0.07	0.07	0.06	0.07	0.03	0.12	0.06	0.13	0.18	0.22	0.15	0.07	2.15
	U	0.51	0.70	0.39	0.46	0.29	0.31	0.12	0.20	0.16	0.14	0.11	0.14	0.17	0.30	0.36	0.67	0.50	0.01	5.56
4 - 7	VS	0.15	0.13	0.12	0.15	0.18	0.30	0.20	0.24	0.20	0.35	0.52	0.93	0.99	0.92	0.53	0.34	0.01	0.	6.25
	MS	0.08	0.12	0.10	0.16	0.18	0.33	0.16	0.18	0.15	0.19	0.27	0.44	0.37	0.37	0.23	0.22	0.01	0.	3.57
	N	0.06	0.10	0.07	0.13	0.12	0.25	0.13	0.11	0.07	0.08	0.10	0.13	0.18	0.21	0.16	0.10	0.02	0.	2.02
	U	1.00	1.03	0.69	0.61	0.52	0.71	0.46	0.60	0.56	0.65	0.38	0.40	0.58	1.28	1.19	1.27	0.23	0.	12.15
8 -12	VS	0.11	0.15	0.14	0.10	0.08	0.13	0.22	0.14	0.14	0.24	0.61	1.29	2.06	1.54	0.51	0.22	0.	0.	7.67
	MS	0.11	0.10	0.04	0.06	0.07	0.20	0.21	0.18	0.28	0.37	0.58	1.13	1.45	0.98	0.25	0.14	0.	0.	6.15
	N	0.07	0.04	0.05	0.05	0.06	0.10	0.10	0.06	0.09	0.14	0.18	0.18	0.31	0.39	0.10	0.08	0.	0.	1.98
	U	0.55	0.44	0.19	0.14	0.12	0.26	0.23	0.25	0.55	0.80	0.72	0.43	0.77	1.52	0.56	0.55	0.00	0.	8.08
13-18	VS	0.06	0.04	0.04	0.04	0.00	0.05	0.17	0.03	0.02	0.07	0.34	0.50	1.20	1.34	0.15	0.11	0.	0.	4.16
	MS	0.09	0.07	0.02	0.03	0.02	0.09	0.16	0.12	0.26	0.58	1.12	1.75	3.43	1.89	0.14	0.12	0.	0.	9.89
	N	0.09	0.02	0.01	0.01	0.01	0.05	0.05	0.08	0.10	0.20	0.29	0.21	0.39	0.38	0.04	0.04	0.	0.	1.95
	U	0.41	0.21	0.05	0.02	0.01	0.03	0.08	0.11	0.37	0.84	1.00	0.41	0.88	1.17	0.12	0.22	0.	0.	5.90
19-24	VS	0.	0.00	0.00	0.01	0.	0.01	0.02	0.01	0.	0.01	0.04	0.02	0.06	0.20	0.01	0.	0.	0.	0.38
	MS	0.05	0.02	0.01	0.01	0.00	0.04	0.08	0.07	0.18	0.51	0.72	0.45	1.99	1.36	0.03	0.02	0.	0.	5.52
	N	0.02	0.02	0.01	0.	0.	0.01	0.02	0.07	0.10	0.19	0.20	0.08	0.30	0.35	0.01	0.01	0.	0.	1.41
	U	0.12	0.06	0.01	0.01	0.	0.	0.01	0.04	0.26	0.63	0.72	0.21	0.52	0.75	0.02	0.04	0.	0.	3.40
OVER 24	VS	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.00	0.01	0.	0.00	0.	0.	0.	0.	0.	0.01
	MS	0.01	0.01	0.	0.	0.	0.	0.01	0.05	0.19	0.45	0.26	0.06	0.75	0.84	0.	0.01	0.	0.	2.62
	N	0.01	0.00	0.00	0.00	0.	0.	0.01	0.01	0.07	0.24	0.14	0.03	0.24	0.26	0.	0.	0.	0.	1.02
	U	0.02	0.03	0.02	0.	0.	0.	0.	0.02	0.17	0.84	0.59	0.14	0.33	0.56	0.01	0.01	0.	0.	2.73
TOTALS	VS	0.47	0.46	0.39	0.44	0.47	0.72	0.76	0.54	0.50	0.89	1.65	3.12	4.58	4.32	1.47	0.88	0.15	0.23	22.03
	MS	0.42	0.42	0.25	0.36	0.45	0.85	0.69	0.67	1.15	2.17	3.02	3.97	8.09	5.54	0.79	0.62	0.09	0.08	29.61
	N	0.35	0.38	0.24	0.33	0.39	0.61	0.37	0.40	0.48	0.91	0.95	0.75	1.48	1.72	0.48	0.45	0.17	0.07	10.54
	U	2.62	2.46	1.35	1.23	0.93	1.32	0.90	1.23	2.07	3.89	3.52	1.74	3.25	5.58	2.25	2.76	0.74	0.01	37.83

SEASON - SUMMER

		NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	VAR.	CALM	TOTAL
0 - 3	VS	0.08	0.07	0.06	0.06	0.06	0.10	0.05	0.08	0.05	0.10	0.13	0.18	0.16	0.16	0.08	0.12	0.06	0.10	1.68
	MS	0.05	0.04	0.04	0.05	0.08	0.12	0.04	0.07	0.04	0.05	0.06	0.12	0.09	0.11	0.04	0.07	0.06	0.05	1.16
	N	0.10	0.10	0.09	0.12	0.10	0.15	0.07	0.06	0.07	0.06	0.08	0.07	0.07	0.11	0.10	0.15	0.10	0.05	1.64
	U	0.42	0.65	0.28	0.37	0.36	0.37	0.18	0.31	0.16	0.32	0.21	0.24	0.18	0.35	0.37	0.57	0.93	0.02	6.28
4 - 7	VS	0.14	0.13	0.10	0.13	0.12	0.21	0.14	0.11	0.13	0.18	0.35	0.78	0.81	0.51	0.38	0.21	0.01	0.	4.45
	MS	0.08	0.08	0.06	0.10	0.16	0.19	0.07	0.10	0.07	0.17	0.22	0.40	0.27	0.22	0.13	0.05	0.01	0.	2.38
	N	0.09	0.07	0.08	0.08	0.16	0.21	0.08	0.09	0.07	0.10	0.09	0.17	0.16	0.22	0.15	0.12	0.03	0.	1.98
	U	1.58	1.55	0.89	1.08	0.89	1.16	0.76	0.98	0.92	1.11	0.84	0.88	0.85	1.66	1.47	1.79	0.87	0.	19.27
8 -12	VS	0.14	0.16	0.02	0.09	0.11	0.08	0.16	0.09	0.06	0.13	0.49	1.18	2.04	1.28	0.44	0.18	0.	0.	6.71
	MS	0.09	0.20	0.03	0.09	0.11	0.12	0.10	0.05	0.06	0.19	0.48	1.25	1.49	0.63	0.13	0.12	0.	0.	5.04
	N	0.05	0.03	0.05	0.04	0.05	0.06	0.04	0.02	0.04	0.08	0.15	0.18	0.30	0.29	0.05	0.03	0.	0.	1.46
	U	0.78	0.54	0.20	0.18	0.18	0.23	0.15	0.22	0.53	1.21	1.06	0.62	0.99	1.95	0.66	0.66	0.01	0.	10.17
13-18	VS	0.04	0.04	0.02	0.03	0.	0.02	0.08	0.01	0.01	0.02	0.11	0.30	1.36	1.44	0.15	0.03	0.	0.	3.65
	MS	0.06	0.05	0.04	0.04	0.01	0.03	0.05	0.03	0.07	0.18	0.62	1.47	4.79	2.03	0.13	0.05	0.	0.	9.64
	N	0.02	0.02	0.01	0.01	0.00	0.02	0.03	0.03	0.03	0.10	0.29	0.24	0.44	0.36	0.02	0.02	0.	0.	1.64
	U	0.24	0.16	0.06	0.04	0.02	0.05	0.05	0.04	0.18	0.87	1.04	0.37	0.97	1.69	0.10	0.13	0.	0.	6.02
19-24	VS	0.	0.01	0.00	0.	0.	0.	0.	0.	0.	0.	0.01	0.	0.03	0.22	0.00	0.	0.	0.	0.27
	MS	0.02	0.03	0.02	0.01	0.00	0.00	0.01	0.02	0.03	0.09	0.18	0.29	2.77	2.70	0.02	0.01	0.	0.	6.19
	N	0.01	0.03	0.08	0.00	0.	0.	0.	0.	0.02	0.07	0.16	0.07	0.51	0.58	0.01	0.00	0.	0.	1.47
	U	0.05	0.07	0.01	0.01	0.	0.	0.02	0.02	0.07	0.27	0.45	0.15	0.48	1.27	0.02	0.01	0.	0.	2.89
OVER 24	VS	0.	0.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.00	0.	0.	0.	0.	0.	0.01
	MS	0.00	0.01	0.	0.	0.	0.00	0.00	0.00	0.01	0.03	0.03	0.02	1.02	1.63	0.00	0.	0.	0.	2.77
	N	0.00	0.01	0.	0.	0.	0.	0.01	0.01	0.01	0.03	0.08	0.02	0.49	0.79	0.00	0.	0.	0.	1.44
	U	0.	0.03	0.01	0.	0.	0.	0.	0.	0.03	0.15	0.24	0.07	0.26	1.02	0.01	0.	0.	0.	1.80
TOTALS	VS	0.40	0.40	0.27	0.31	0.29	0.40	0.42	0.29	0.25	0.44	1.09	2.45	4.39	3.61	1.06	0.53	0.06	0.10	16.77
	MS	0.30	0.31	0.19	0.27	0.37	0.46	0.27	0.27	0.27	0.70	1.58	3.54	10.44	7.33	0.46	0.30	0.07	0.05	27.19
	N	0.29	0.25	0.23	0.25	0.32	0.44	0.23	0.21	0.23	0.43	0.85	0.76	1.96	2.35	0.33	0.31	0.12	0.05	9.62
	U	3.08	3.00	1.45	1.67	1.45	1.81	1.15	1.57	1.88	3.94	3.83	2.32	3.73	7.93	2.63	3.17	1.81	0.02	46.42

TABLE II.3-E-4 (Continued)

SEASON = FALL

		NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	VAR.	CALM	TOTAL
0 - 3	VS	0,31	0,21	0,25	0,32	0,43	0,60	0,34	0,35	0,32	0,31	0,31	0,55	0,54	0,66	0,63	0,52	0,30	0,87	7,91
	MS	0,20	0,21	0,19	0,27	0,38	0,54	0,23	0,20	0,12	0,12	0,18	0,17	0,23	0.37	0,29	0,39	0,15	0,60	4,84
	N	0,37	0,43	0,38	0,41	0,40	0,51	0,21	0,16	0,15	0,11	0,08	0,13	0,16	0,35	0,46	0,37	0,16	0,39	5,24
	U	0,71	0,97	0,57	0,63	0,48	0,31	0,14	0,11	0,06	0,13	0,09	0,11	0,15	0.31	0,53	0,70	0,36	0,08	6,42
4 - 7	VS	0,28	0,23	0,17	0,18	0,28	0,50	0,47	0,43	0,38	0,49	0,67	1,20	1,53	1.48	0,92	0,49	0,02	0.	9,73
	MS	0,19	0,12	0,16	0,15	0,27	0,44	0,29	0,17	0,19	0,20	0,19	0,33	0,51	0,70	0,47	0,32	0,01	0.	4,71
	N	0,13	0,13	0,04	0,12	0,25	0,31	0,13	0,09	0,07	0,08	0,08	0,13	0,21	0.54	0,36	0,15	0,01	0.	2,85
	U	0,88	0,74	0,46	0,48	0,60	0,52	0,23	0,18	0,25	0,24	0,21	0,17	0,36	0.94	1,23	1,22	0,08	0.	8,81
8 -12	VS	0,17	0,08	0,06	0,06	0,04	0,17	0,31	0,11	0,13	0,32	0,68	1,50	2,49	2.37	0,77	0,27	0,	0.	9,55
	MS	0,10	0,05	0,03	0,03	0,10	0,23	0,27	0,16	0,22	0,43	0,48	0,76	1,26	1.45	0,41	0,13	0,	0.	6,10
	N	0,05	0,05	0,01	0,03	0,03	0,09	0,08	0,07	0,05	0,07	0,15	0,11	0,23	0,60	0,17	0,06	0,	0.	1,85
	U	0,45	0,26	0,05	0,03	0,05	0,11	0,04	0,08	0,17	0,28	0,35	0,20	0,32	1.11	0,56	0,44	0,00	0.	4,50
13-18	VS	0,06	0,03	0,01	0,02	0,00	0,05	0,10	0,03	0,02	0,08	0,25	0,43	1,54	1.93	0,21	0,04	0.	0.	4,79
	MS	0,09	0,05	0,00	0,02	0,01	0,09	0,15	0,18	0,31	0,63	0,87	0,97	2,18	1,85	0,17	0,12	0,	0.	7,70
	N	0,04	0,02	0,00	0,00	0.	0,04	0,04	0,07	0,09	0,14	0,21	0,11	0,26	0,37	0,09	0,05	0,	0.	1,55
	U	0,25	0,22	0,01	0.	0.	0,03	0,03	0,03	0,10	0,34	0,45	0,14	0,42	0,63	0,09	0,13	0,	0.	2,78
19-24	VS	0.	0,00	0,00	0.	0.	0.	0,01	0,01	0,01	0,01	0,04	0,03	0,09	0.19	0.	0,00	0.	0.	0,38
	MS	0,05	0,03	0,03	0.	0.00	0,01	0,05	0,18	0.27	0,57	0,54	0,24	0,99	1.04	0,03	0,02	0.	0.	4,04
	N	0,00	0,01	0,01	0.	0.	0,02	0,02	0,04	0,10	0,19	0,20	0,02	0,13	0,23	0,01	0,02	0.	0.	1,00
	U	0,04	0,03	0,01	0.	0.	0.	0,01	0,01	0.07	0,32	0,34	0,08	0,23	0.37	0,01	0,02	0.	0.	1,55
OVER 24	VS	0.	0.	0.	0.	0.	0.	0,	0,01	0,01	0.	0.00	0.	0.	0.	0.	0.	0.	0.	0,02
	MS	0.	0,01	0.	0.	0.	0.	0,02	0,08	0.30	0,43	0,21	0,07	0,31	0,40	0,01	0.	0.	0.	1,84
	N	0,01	0,01	0,00	0,	0.	0.	0,01	0,02	0.09	0,19	0,09	0,03	0,07	0.13	0,00	0,00	0,	0.	0,66
	U	0,01	0,05	0,01	0,	0.	0.	0,	0,01	0.09	0,39	0,24	0,07	0,09	0.21	0,01	0.	0,	0,	1,16
TOTALS	VS	0,83	0,66	0,49	0,58	0,76	1,32	1,22	0,94	0,87	1,21	1,95	3,70	6,18	6,63	2,52	1,32	0,32	0,87	32,38
	MS	0,63	0,46	0,40	0,46	0,76	1,32	1,02	0,98	1,40	2,38	2,48	2,53	5,49	5.82	1,37	0,97	0,16	0,60	29,24
	N	0,60	0,64	0,47	0,56	0,68	0,96	0,49	0,46	0,56	0,78	0,82	0,54	1,08	2,23	1,09	0,65	0,16	0,39	13,16
	U	2,34	2,17	1,10	1.14	1.13	0,97	0,45	0,42	0,75	1.71	1.69	0,77	1,57	3.56	2,43	2,50	0,44	0,08	25,23

SEASON = WINTER

		NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	VAR.	CALM	TOTAL
0 - 3	VS	0,29	0,35	0,23	0,30	0,36	0,58	0,39	0,37	0,27	0,30	0,31	0,48	0,41	0,61	0,50	0,54	0,35	0,73	7,36
	MS	0,38	0,36	0,34	0,42	0,69	0,82	0,48	0,39	0,24	0,24	0,20	0,40	0,46	0,66	0,64	0,59	0,23	1,30	8,83
	N	0,62	0,64	0,51	0,66	0,74	0,91	0,55	0,32	0.23	0,22	0,21	0,39	0,45	0.75	0,89	0,91	0,14	1,42	10,56
	U	0,30	0,25	0,20	0,15	0,12	0,07	0,03	0,05	0,04	0,03	0,01	0,06	0,08	0,14	0,22	0,23	0,05	0,06	2,08
4 - 7	VS	0,29	0,21	0,16	0,21	0,22	0,33	0,30	0,36	0,25	0,36	0,48	0,93	0,99	1.10	0,92	0,53	0,06	0.	7,70
	MS	0,33	0,29	0,22	0,21	0,26	0,47	0,31	0,23	0,20	0,27	0,27	0,53	0,84	1,42	1,08	0,65	0,03	0.	7,62
	N	0,20	0,21	0,18	0,16	0,23	0,28	0,23	0,09	0,07	0,14	0,16	0,23	0,53	1,23	0,66	0,34	0,00	0,	4,93
	U	0,31	0,25	0,14	0,12	0,10	0,09	0,04	0,03	0,05	0,02	0,02	0,05	0,12	0.64	0,55	0,41	0,01	0,	2,96
8 -12	VS	0,09	0,05	0,03	0,03	0,05	0,13	0,15	0,12	0,13	0,29	0,59	0,95	1,41	1.79	0,70	0,15	0,	0,	6,67
	MS	0,15	0,07	0,03	0,06	0,11	0,30	0,19	0,13	0,25	0,36	0,45	0,69	1,67	3.10	0,72	0,18	0,00	0,	8,45
	N	0,07	0,06	0,03	0,01	0,03	0,09	0,06	0,03	0,05	0,07	0,08	0,10	0,86	1,87	0,28	0,09	0,	0,	3,78
	U	0,14	0,08	0,03	0,01	0,01	0,02	0,01	0,02	0,08	0,04	0,10	0,07	0,28	1.07	0,29	0,14	0,	0,	2,40
13-18	VS	0,05	0,03	0,	0,00	0.	0,04	0,04	0,05	0,09	0,19	0,31	0,51	0,89	1.41	0,17	0,03	0,	0,	3,81
	MS	0,15	0,05	0,01	0,01	0,05	0,08	0,16	0,26	0,36	0,78	0,88	0,76	1,73	3.16	0,29	0,12	0,	0,	8,85
	N	0,07	0,01	0,00	0,01	0,01	0,02	0,02	0,03	0,07	0,14	0,15	0,08	0,67	1.21	0,08	0,06	0,	0,	2,62
	U	0,13	0,03	0,00	0,00	0,	0,	0,00	0,01	0,08	0,10	0,20	0,11	0,26	0.44	0,06	0,08	0,	0,	1,51
19-24	VS	0,	0,	0,	0,	0.	0,01	0,02	0,01	0.04	0,07	0,05	0,05	0,08	0.12	0,00	0,	0,	0,	0.45
	MS	0,04	0,03	0,	0,	0,01	0,03	0,10	0,18	0,36	0,96	0,56	0,35	0,44	0.70	0,05	0,03	0,	0,	3,85
	N	0,03	0,01	0,	0,00	0,01	0,	0,01	0,03	0,09	0,14	0,12	0,03	0,07	0.18	0,01	0,06	0,	0,	0,79
	U	0,03	0,04	0,01	0,	0.	0,00	0,00	0,01	0,04	0,13	0,14	0,03	0,06	0.14	0,00	0,03	0,	0,	0,67
OVER 24	VS	0,	0,	0,	0,	0.	0,00	0,01	0,01	0,04	0,04	0,01	0,01	0,	0.	0,	0,	0,	0,	0,12
	MS	0,02	0,00	0,	0,	0,	0,02	0,06	0,21	0,69	0,99	0,41	0,11	0,12	0.13	0,01	0,02	0,	0,	2,79
	N	0,03	0,02	0,	0,	0.	0,	0,01	0,03	0,14	0,23	0,05	0,02	0,01	0.02	0,	0,03	0,	0,	0,61
	U	0,04	0,08	0,	0,	0.	0,	0,	0,01	0,08	0,20	0,16	0,02	0,01	0.04	0,00	0,01	0,	0,	0,57
TOTALS	VS	0,72	0,83	0,42	0,55	0,63	1,10	0,91	0,92	0,81	1,26	1,75	2,92	3,79	5,03	2,30	1,25	0,41	0,73	26,12
	MS	1,07	0,81	0,59	0,70	1.12	1,73	1,30	1,39	2.10	3,61	2,77	2,85	5,26	9.17	2,77	1,59	0,26	1,30	40,39
	N	1,02	0,96	0,72	0,83	1.01	1,30	0,87	0,52	0,66	0,93	0,77	0,85	2,60	5.26	1,93	1,49	0,14	1,42	23,29
	U	0,95	0,66	0,41	0,29	0,23	0,18	0,08	0,13	0,36	0,53	0,64	0,34	0,80	2.46	1,13	0,91	0,06	0,06	10,20

TABLE II.3-E-4 (Continued)

SEASON - ANNUAL

		NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	VAR.	CALM	TOTAL
0 - 3	VS	0.21	0.21	0.15	0.20	0.26	0.38	0.23	0.23	0.20	0.23	0.22	0.40	0.34	0.43	0.37	0.35	0.21	0.48	5.11
	MS	0.17	0.18	0.16	0.21	0.33	0.42	0.20	0.18	0.12	0.12	0.13	0.21	0.22	0.31	0.28	0.29	0.13	0.50	4.15
	N	0.30	0.34	0.27	0.33	0.36	0.44	0.22	0.15	0.13	0.11	0.10	0.18	0.18	0.33	0.41	0.41	0.13	0.48	4.87
	U	0.49	0.64	0.36	0.40	0.31	0.27	0.12	0.17	0.10	0.16	0.10	0.14	0.14	0.27	0.37	0.54	0.46	0.04	5.09
4 - 7	VS	0.21	0.18	0.14	0.17	0.20	0.33	0.28	0.28	0.24	0.35	0.50	0.96	1.08	1.00	0.69	0.39	0.02	0.	7.02
	MS	0.17	0.15	0.13	0.15	0.22	0.36	0.21	0.17	0.15	0.21	0.24	0.42	0.50	0.68	0.47	0.31	0.02	0.	4.56
	N	0.12	0.13	0.10	0.12	0.19	0.26	0.14	0.10	0.07	0.10	0.11	0.16	0.27	0.55	0.35	0.18	0.01	0.	2.94
	U	0.94	0.90	0.55	0.58	0.53	0.62	0.37	0.45	0.45	0.51	0.37	0.38	0.48	1.13	1.11	1.18	0.30	0.	10.84
8 -12	VS	0.13	0.11	0.08	0.07	0.07	0.13	0.21	0.11	0.12	0.24	0.59	1.23	2.00	1.74	0.60	0.20	0.	0.	7.65
	MS	0.11	0.08	0.03	0.06	0.10	0.21	0.19	0.13	0.20	0.34	0.50	0.96	1.47	1.53	0.38	0.14	0.00	0.	6.43
	N	0.06	0.04	0.03	0.03	0.04	0.09	0.07	0.04	0.06	0.09	0.14	0.14	0.42	0.78	0.15	0.06	0.	0.	2.26
	U	0.48	0.33	0.12	0.09	0.09	0.15	0.11	0.14	0.34	0.59	0.56	0.33	0.59	1.42	0.52	0.45	0.00	0.	6.31
13-18	VS	0.05	0.03	0.02	0.02	0.00	0.04	0.10	0.03	0.03	0.09	0.25	0.43	1.25	1.53	0.17	0.05	0.	0.	4.10
	MS	0.10	0.05	0.02	0.02	0.02	0.07	0.13	0.15	0.25	0.54	0.87	1.24	3.04	2.23	0.18	0.10	0.	0.	9.03
	N	0.05	0.01	0.01	0.01	0.00	0.03	0.04	0.05	0.07	0.14	0.24	0.16	0.44	0.58	0.06	0.04	0.	0.	1.94
	U	0.26	0.13	0.03	0.01	0.01	0.03	0.04	0.05	0.18	0.54	0.68	0.26	0.64	0.98	0.09	0.14	0.	0.	4.07
19-24	VS	0.	0.00	0.00	0.00	0.	0.00	0.01	0.01	0.01	0.02	0.04	0.02	0.06	0.18	0.00	0.00	0.	0.	0.37
	MS	0.04	0.03	0.01	0.00	0.00	0.02	0.06	0.11	0.21	0.53	0.50	0.33	1.55	1.45	0.03	0.02	0.	0.	4.91
	N	0.02	0.02	0.00	0.00	0.00	0.01	0.01	0.03	0.08	0.15	0.17	0.05	0.25	0.34	0.01	0.02	0.	0.	1.17
	U	0.06	0.05	0.01	0.00	0.	0.00	0.01	0.02	0.11	0.34	0.41	0.12	0.32	0.63	0.01	0.03	0.	0.	2.13
OVER 24	VS	0.	0.00	0.	0.	0.	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.	0.	0.	0.	0.	0.04
	MS	0.01	0.01	0.	0.	0.	0.01	0.02	0.08	0.30	0.47	0.22	0.06	0.55	0.76	0.00	0.01	0.	0.	2.50
	N	0.01	0.01	0.00	0.00	0.	0.	0.01	0.02	0.08	0.17	0.09	0.03	0.21	0.30	0.00	0.01	0.	0.	0.93
	U	0.02	0.03	0.01	0.	0.	0.	0.	0.01	0.09	0.40	0.31	0.08	0.17	0.46	0.01	0.00	0.	0.	1.57
TOTALS	VS	0.60	0.54	0.39	0.47	0.53	0.88	0.83	0.67	0.61	0.95	1.61	3.05	4.73	4.89	1.83	1.00	0.23	0.48	24.29
	MS	0.60	0.50	0.36	0.45	0.67	1.08	0.82	0.83	1.22	2.21	2.46	3.23	7.33	6.96	1.34	0.87	0.14	0.50	31.57
	N	0.56	0.55	0.42	0.49	0.60	0.82	0.49	0.40	0.48	0.76	0.85	0.72	1.78	2.88	0.95	0.72	0.15	0.48	14.11
	U	2.25	2.08	1.08	1.09	0.94	1.07	0.65	0.84	1.27	2.53	2.43	1.30	2.35	4.90	2.11	2.34	0.77	0.04	30.03

TABLE II.3-E-5

HANFORD STABILITY DEFINITION AND COMPARISON WITH PASQUILL CLASSES AS DEFINED IN USNRC REGULATORY GUIDE 1.23

Hanford Diffusion Model		Regulatory Guide 1.23	
Class	$\Delta T/\Delta z$ (°F/200 ft)	Pasquill Class	$\Delta T/\Delta z$ (°F/200 ft)
		A	less than -2.1
Unstable	less than or equal to -1.5	B	-2.1 to -1.9
Neutral	-1.4 to -0.5	C	-1.9 to -1.6
		D	-1.6 to -0.6
Moderately Stable	-0.4 to 3.4	E	-0.6 to 1.6
		F	1.6 to 4.4
Very Stable	greater than or equal to 3.5	G	greater than 4.4

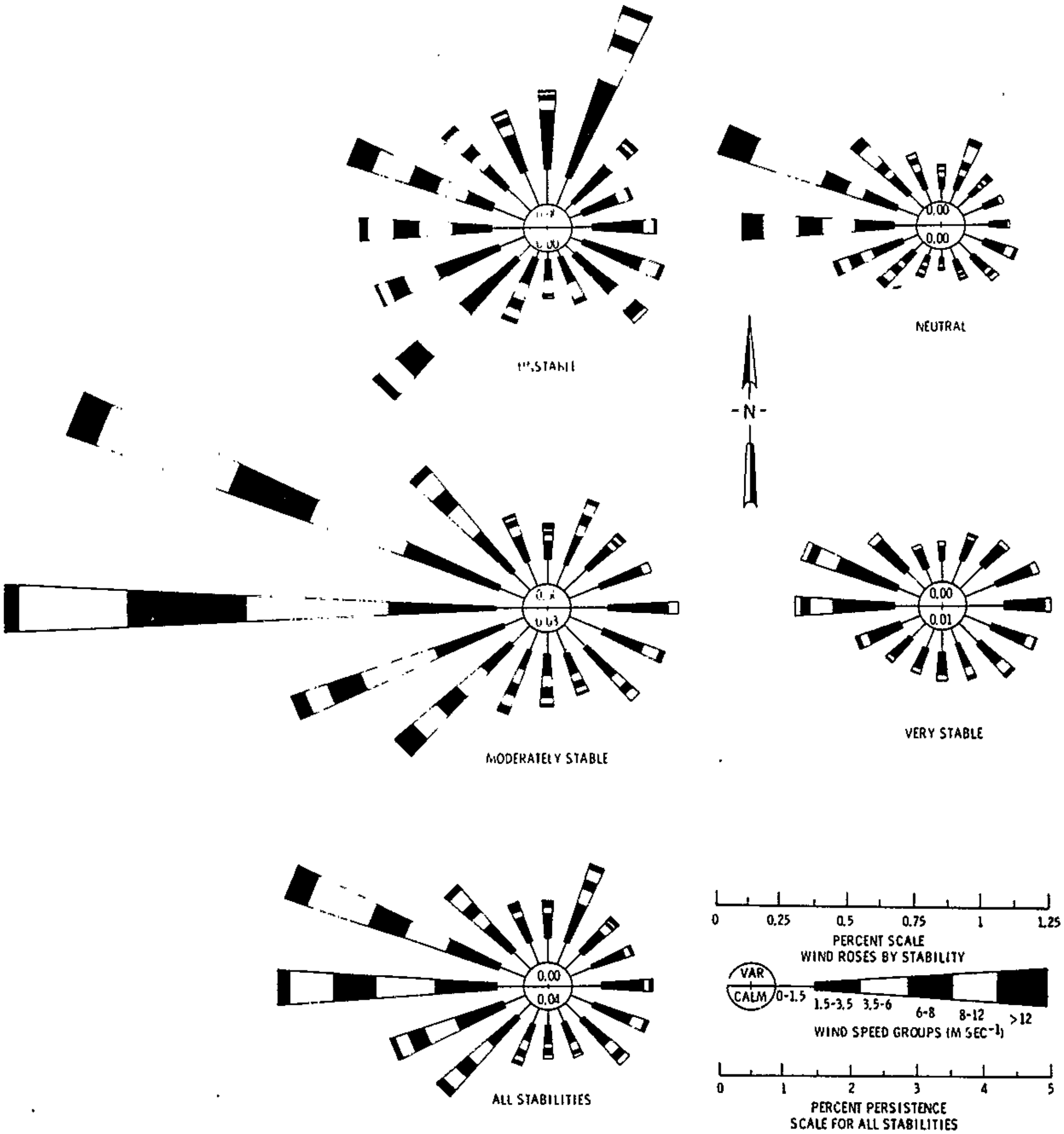

FIGURE II.3-E-8 WIND ROSES AS A FUNCTION OF STABILITY AND FOR ALL STABILITIES AT HANFORD GENERATING PLANT BASED ON WINDS AT 200 FT AND AIR TEMPERATURE BETWEEN 3 FT AND 200 FT FOR THE PERIOD JANUARY 29, 1970 TO JANUARY 28, 1971, (the points of the rose represent the directions from which the winds come)

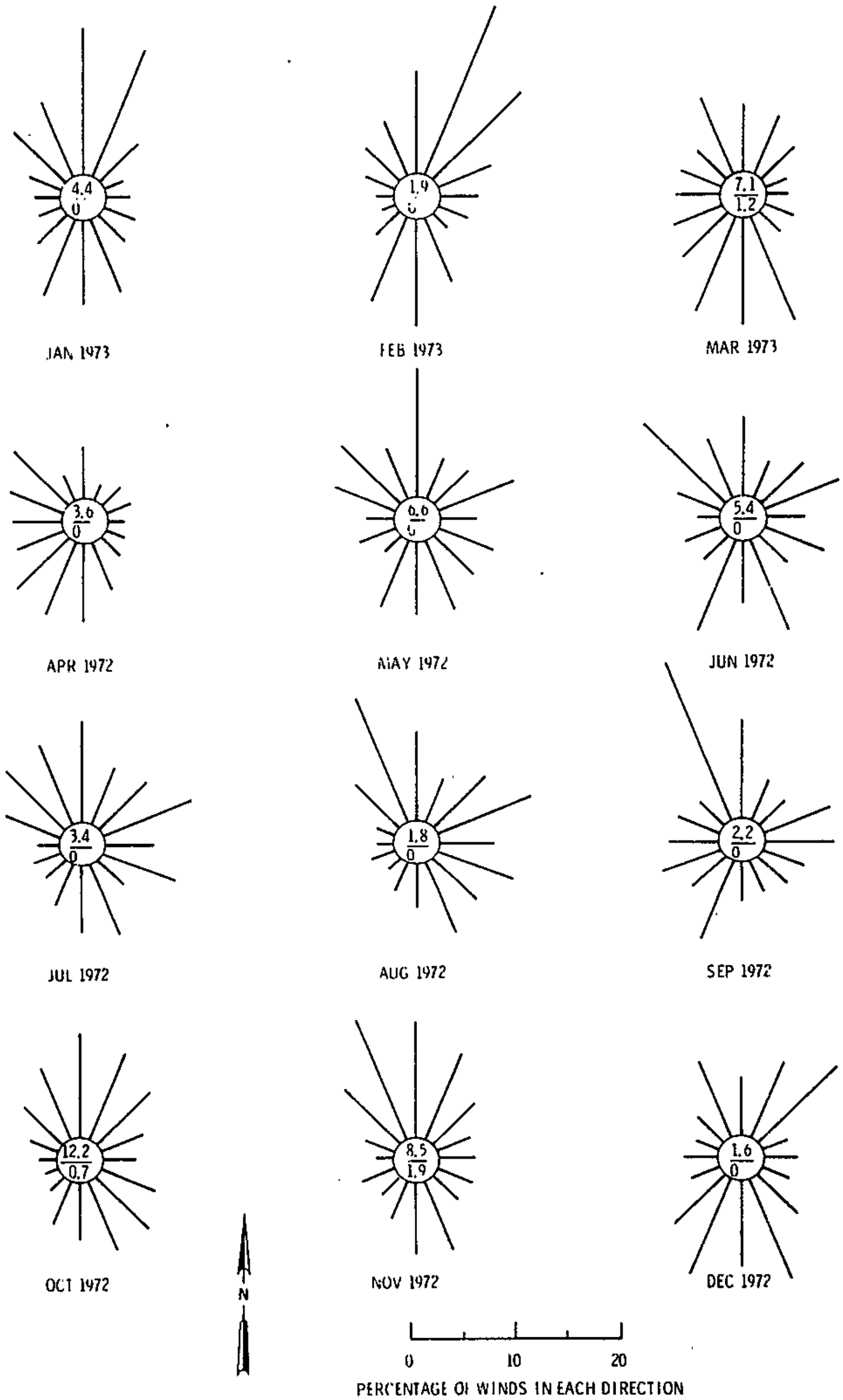

FIGURE II.3-E-9 MONTHLY AVERAGE WIND ROSES FOR THE WNP-2 SITE BASED ON 1 YEAR OF DATA TAKEN AT 23 FEET (the numbers in the center are the percentages of calm [top number] and variable [bottom number] winds) (the points of the rose represent the directions from which the winds come)

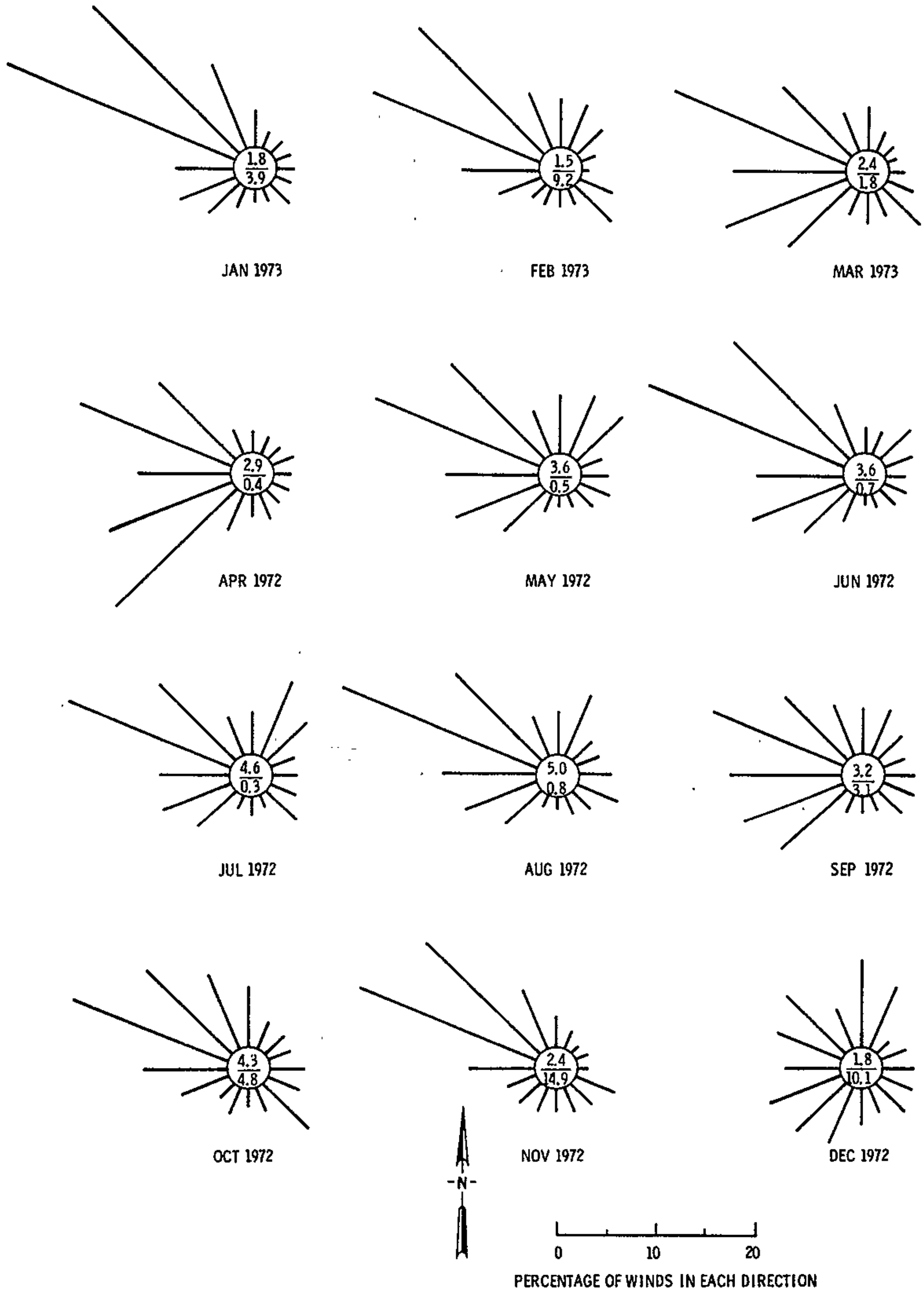

FIGURE II.3-E-10 MONTHLY AVERAGE WIND ROSES FOR THE HMS BASED ON 1 YEAR OF DATA TAKEN AT 50 FEET (the numbers in the centers are the percentages of calm [top numbers] and variable [bottom number] winds) (the points of the rose represent the directions from which the winds come)

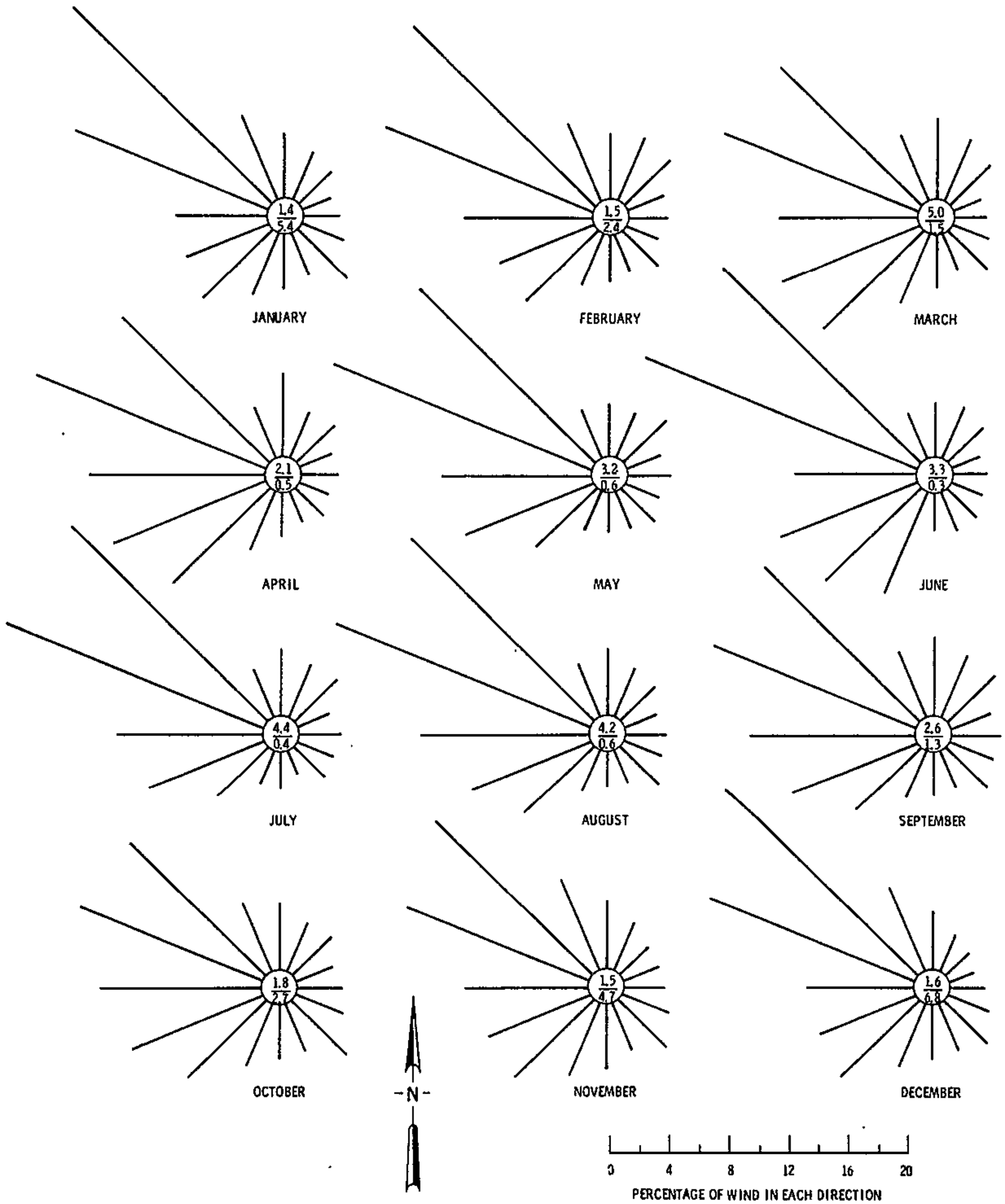

FIGURE II.3-E-11 MONTHLY AVERAGE WIND ROSES FOR HMS BASED ON 50 FEET WIND DATA, 1955-1970 (the numbers in the centers are the percentages of calm [top numbers] and variable [bottom numbers] winds) (the points of the rose represent the directions from which the winds come)

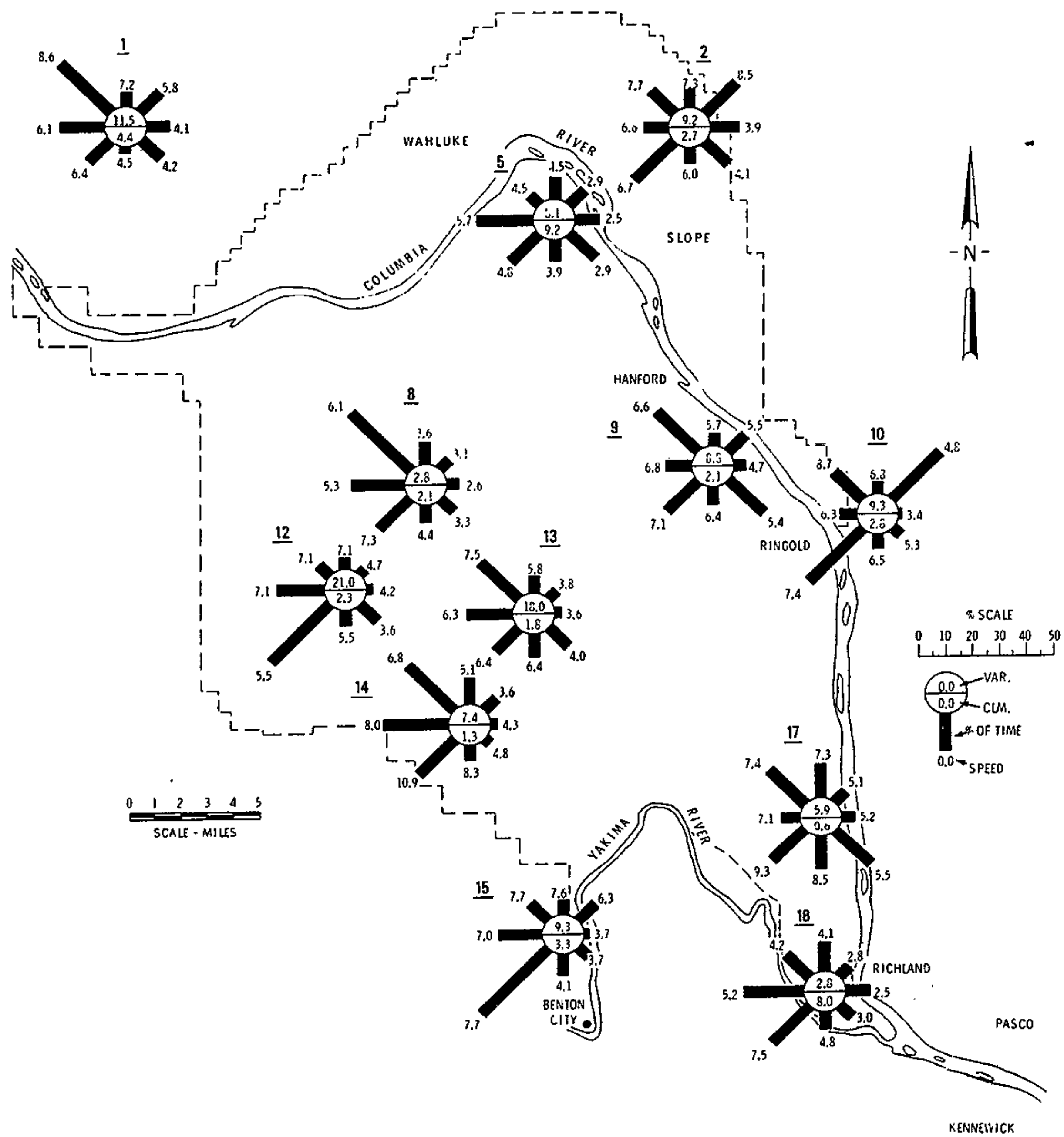

FIGURE II.3-E-12 SURFACE WIND ROSES FOR VARIOUS LOCATIONS ON AND SURROUNDING THE HANFORD SITE BASED ON FIVE-YEAR AVERAGES (1952-1956). SPEEDS ARE GIVEN IN MILES PER HOUR. (the points of the rose represent the directions from which the winds come)

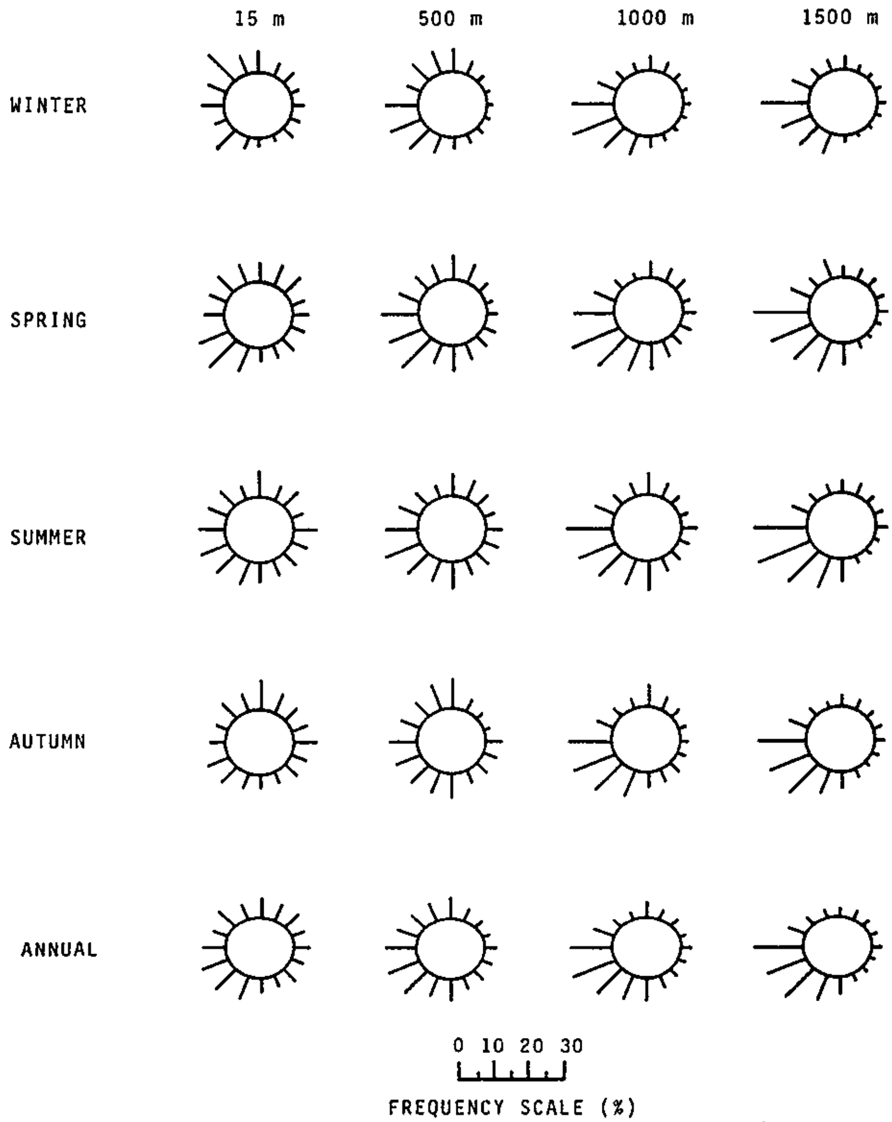

FIGURE II.3-E-13 SEASONAL AND ANNUAL WIND ROSES FROM PIBAL (1500, 1000, 500m) AND TOWER (15m) DATA

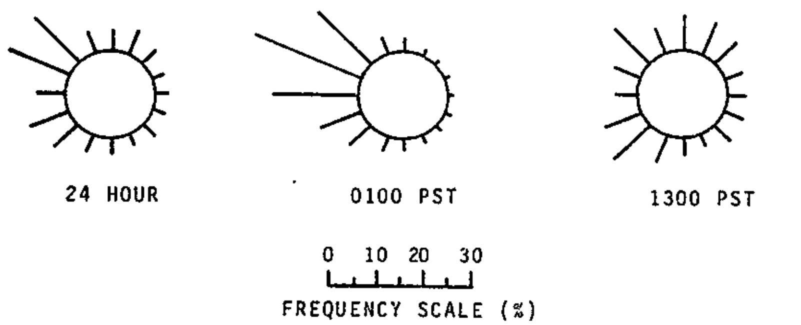

FIGURE II.3-E-14 WIND ROSES AT 15 METERS FOR 0100 PST, 1300 PST AND 24 HOUR AVERAGE

The wind rose plots for the 1000 and 1500 m levels are very much alike, possibly indicating that both levels are generally above the influence of the boundary layer. The primary seasonal difference at these two levels lies in the average wind speeds. The average speeds for almost all directions have their maxima in the winter and minima in the summer. The predominant frequencies of direction for all seasons seem to be from the west through southwest.

II.3-E.4.1 Strong Winds

The highest monthly wind speeds and peak gusts recorded at the HMS are tabulated in Table II.3-E-6. Figure II.3-E-15 indicates the return probability of any peak wind gust, again due to any cause. For example, a gust of 96 mph might be expected to occur once every 500 years.

TABLE II.3-E-6

HIGH WIND STATISTICS AT HMS - HIGHEST AVERAGE MONTHLY WIND SPEED AND PEAK GUSTS

Month	Highest Average	Year	Peak Gust Speed	Peak Gust Dir	Peak Gust Year	Month	Highest Average	Year	Peak Gust Speed	Peak Gust Dir	Peak Gust Year
Jan	10.3[a]	1972	80[b]	S	1972	Aug	9.1	1946	66	SW	1961
Feb	9.4	1961	63	SW	1965	Sept	9.2	1961	65	SSW	1953
Mar	10.7	1964	70	SW	1956	Oct	9.1	1946	63	SSW	1950
Apr	11.1	1959	60	WSW	1969	Nov	7.9	1945	64	SSW	1949
May	10.5	1965+	71	SSW	1948	Dec	8.3	1968	71	SW	1955
June	10.7	1949	72	SW	1957	YEAR	8.3	1968+	72[b]	SW	JUNE 1957
July	9.6	1963	55	WSW	1968						

(a) The average speed for January 1972 was 10.3 mph.
(b) On January 11, 1972, a new all-time record peak gust of 80 mph was established.

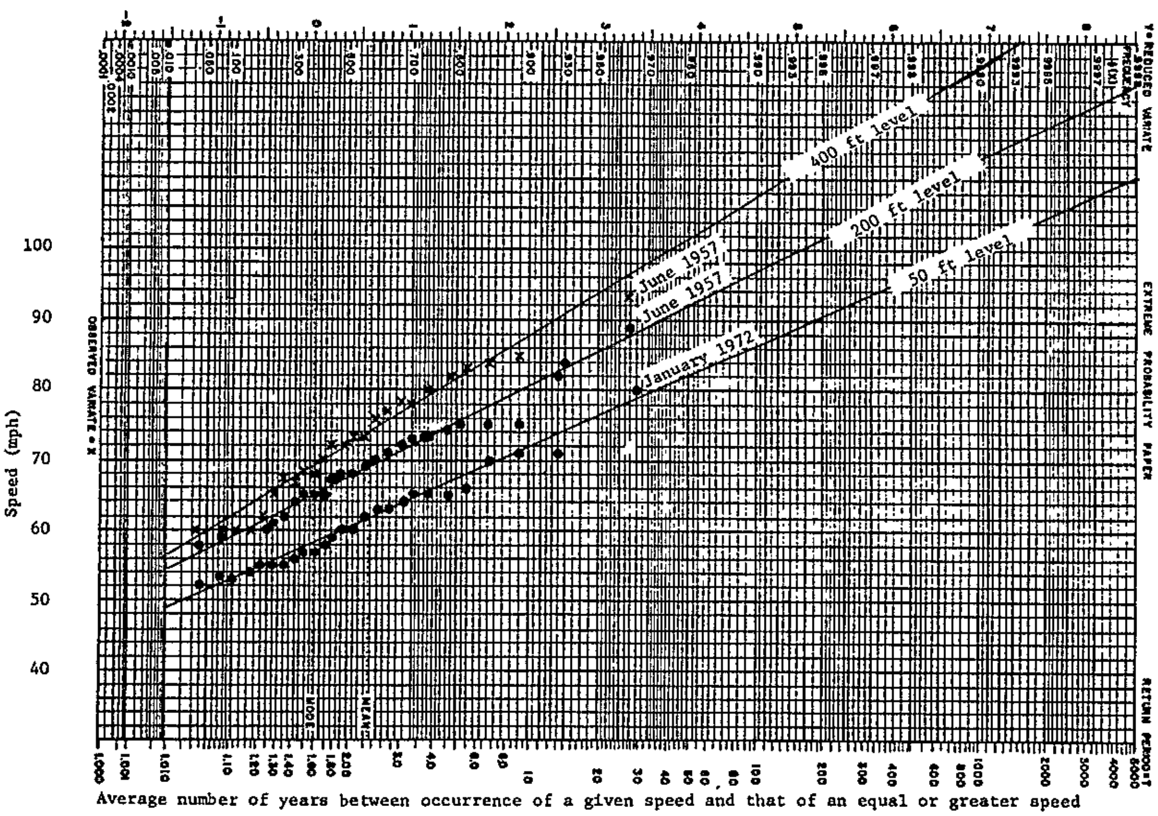

FIGURE II.3-E-15 PEAK WIND GUST RETURN PROBABILITY DIAGRAM

At certain locations other than the HMS site, strong winds can be expected due to orographic channeling or to elevation effects. The U.S. Army Corps of Engineers made a limited three-year study[10] of surface winds along the Columbia River from McNary Dam to Wallula, upstream 20 miles. Their findings represent what might be encountered elsewhere on the Columbia River in the vicinity of the Hanford area.

The Corps of Engineers recorded wind data demonstrate that moderate to strong surface winds tend to blow within and approximately parallel to the river channel, with the predominant wind movement from west to east. However, winds 10 to 30 degrees from the river alignment are not uncommon. Some evidence, including smoke trails, indicates that at times a core of higher speed wind occurs over the river. This wind core appears to change position slightly within short time periods. Aerial observations of smoke and dust suggest that in the more entrenched reaches of the Columbia River it may ride up on the steep outside slopes of river bends and possibly even develop reflection meanders downwind of entrenched bends. The low-level wind field is suspected to undergo vertical as well as horizontal compression and expansion. Under certain meteorological conditions the core of stronger mid-river wind appears to be nonexistent or very weak.

One period of notably strong winds occurred at Hanford on January 11, 1972.[11] The passage of an occluded front during the morning hours preceded strong gale force winds, with gusts exceeding hurricane force. Tables II.3-E-7 and 8 list various peak wind gusts recorded or observed on and in the immediate vicinity of the Hanford site and show the patterns of the extreme winds that occurred at various locations on the site.

TABLE II.3-E-7

EXAMPLE OF AN EXTREME HIGH WIND OCCURRENCE, DATA RECORDED BY THE ERDA (BATTELLE) NETWORK OF WIND SENSORS ON JANUARY 11, 1972

Observation Site	Location[(a)]	Elevation (MSL-ft)	Height of Sensor Above Ground (ft)	Wind (mph)	Time (PST)
Hanford Met Tower	1	727	7	64	0345
Hanford Met Tower	1	727	50	80	0345
Hanford Met Tower	1	727	100	79	0835
Hanford Met Tower	1	727	150	--[(b)]	--[(b)]
Hanford Met Tower	1	727	200	84	0835
Hanford Met Tower	1	727	250	82	0837
Hanford Met Tower	1	727	300	84[(c)]	0835
Hanford Met Tower	1	727	400	84	0827
Rattlesnake Mountain	11.0 S	3568	10	150+[(d)]	0546-0924
Army Loop Road	7.5 ESE	555	50	60+[(e)]	0900-1700
Central Wahluke Slope[(f)]	12.0 NNW	660	23	32	0155
Yakima Barricade[(f)]	6.0 WNW	795	23	45	0455
Gable Mountain[(f)]	7.0 ENE	1100	23	41	0055
Wye Barricade[(f)]	11.5 SE	550	23	43	0055
Prosser Barricade[(f)]	14.5 SE	450	23	35	0055
Richland Barricade[(f)]	26.5 SE	390	23	33	0355
Rattlesnake Mountain[(f)]	11.0 S	3568	9	--[(g)]	--[(g)]
Eastern Wahluke Slope[(f)]	17.5 NE	800	23	34	0455
Ringold[(f)]	17.5 E	620	23	30	0355

(a) Distance (miles) and direction from the Hanford Meteorology Tower located at 46° 34'N latitude, 119° 36'W longitude, approximately 25 miles NW of Richland, Washington.
(b) Equipment malfunction.
(c) Interpolated value.
(d) Limit of recorder 150 mph, also visually observed.
(e) Temporary research equipment - limit of recorder 60 mph.
(f) Radio-Telemetered Automatic Weather Station - highest hourly integrated wind speed, not equipped with gust recorded.
(g) Power outage for telemetering equipment during periods of peak winds.

TABLE II.3-E-8

EXAMPLE OF EXTREME HIGH WIND OCCURRENCE, WIND OBSERVATIONS ON OR NEAR THE HANFORD RESERVATION FOR JANUARY 11, 1972

Observation Site	Location[a]	Height of Sensor Above Ground (ft)	Type of Data Readout	Peak Wind (mph)	Time (PST)	Operating Agency	Remarks
FFTF	15.0 SE	13	Analog Tape	--	--	AEC(HEDL)	Recorder limit, 60 mph Equipment malfunction
FFTF	15.0 SE	25	Dial	65	A.M.	AEC(Bechtel)	Visual observation
N Reactor	8.0 NNE	200	Analog Tape	42	0830-0900	AEC(DUN)	Recorder not activated; visual observation
Richland Airport	22.0 SE	30	Strip Chart	74	0245	AEC(Battelle)	
Priest Rapids Dam	18.0 NW	30	Dial	100+	0700+	Grant County PUD	Visual observation; dial limit - 100 mph
Richland By-Pass Highway	24.0 SE	35	Dial	100+	A.M.	Teleprompter Cable TV Co.	Visual observation; dial limit - 100 mph
Tri-Cities Airport (Pasco)	30.0 SE	16	Dial	63	A.M.	Hughes Air west	Visual observation
KONA Radio (Pasco)	32.0 SE	30	Manometer	78	1000	KONA Radio	Visual observation
Columbia TV (Kennewick)	35.0 SE	40	Dial	100+	1200-1300	Columbia TV	Visual observation; dial limit - 100 mph

(a) Miles from Hanford Meteorology Station

Perhaps the "windiest" site on the Hanford Reservation is the crest of Rattlesnake Mountain, at an elevation of 3568 feet MSL, about 11 miles south of the HMS. Wind data are regularly recorded at this site but are not available in summary form. Some selected wind observations are listed in Table II.3-E-9 to give some insight into wind characteristics on Rattlesnake Mountain. These winds are considerably reduced at the elevations of most of the Hanford site, as shown in Figure II.3-E-15, where the peak wind gust return probability is given for three elevations.

TABLE II.3-E-9

SELECTED RATTLESNAKE MOUNTAIN WIND OBSERVATIONS

OCCURRENCE	AVERAGE SPEED (mph)	DURATION	PEAK GUSTS (mph)
2-27-66	83	-	103
1-4-67	-	-	75
1-29-67	-	-	114
2-17-67	110	1/2 hr	136.5
10-3-67	97	3 hrs	129
3-22-69	100	1 1/4 hrs	-
3-22-69	120	1/4 hr	142.5
12-30-70	100	-	118.5
1-9-71	67	1 hr	96.5
1-24-71	-	-	117
2-10-71	-	-	120
12-4-71	60	-	72
12-5-71	45	-	63
12-8-71	-	-	87
1-11-72	120	3/4 hr	150+ limit of recorder

II.3-E.4.2 Tornadoes

Two funnel clouds and one small tornado (June 16, 1948) have been observed in 29 years at Hanford. The nearest reported tornado damage was at Yakima, about 45 miles west (April 30, 1957) and at Wallula Junction, about 50 miles southeast (June 26, 1958). No loss of life or extensive property damage was reported from any of the tornadoes observed in this region.[12]

On the average the state of Washington experiences less than one tornado each year.[12] Within a 100-mile radius of the HMS, only fourteen tornadoes have been reported since 1916[13] (listed in Table II.3-E-10) of which only five were associated with any damage. An extensive survey of tornadoes in the three northwestern states (Washington, Oregon and Idaho) was completed in 1970.[14] The results indicate that tornadoes in this area occur primarily in "alleys." The locations of these "alleys" are shown in Figure II.3-E-16 along with the locations of tornadoes recorded in the tri-state area during the 20-year period 1950-1969.

The tornado survey data was analyzed[15] to determine the probability of a tornado striking the Exxon Nuclear Company, Inc. (formerly the Jersey Nuclear Company) fuel fabrication facility approximately 25 miles southeast of the HMS. The analysis indicates the probability of tornado occurrence in the vicinity of the site as six chances in a million during any given year or about one chance in four thousand during a 40-year plant life.

The maximum wind speed for the Hanford site is estimated as 175 mph.[32] This agrees with the estimate of most probable maximum wind speed of 174 mph derived in the statistical tornado study made by Exxon Nuclear Company, Inc.[15]

TABLE II.3-E-10

TORNADO HISTORY WITHIN 100 MILES OF HMS

DATE	LOCATION
June 26, 1916	Walla Walla, Washington
April 15, 1925	Condon, Oregon
September 2, 1936	Walla Walla, Washington
May 20, 1948	Yakima, Washington
May 29, 1948	Yakima, Washington
June 11, 1948	Ephrata, Washington
June 16, 1948	Hanford Reservation
May 9, 1956	Kennewick, Washington
April 12, 1957	Ione, Oregon
April 30, 1957	Yakima, Washington
May 6, 1957	Harrington, Washington
April 24, 1958	Walla Walla, Washington
June 26, 1958	Wallula Junction, Washington
March 14, 1966	Little Goose Dam, Washington

II.3-E.4.3 Dust Devils

Dust devils are frequently observed phenomena on the Hanford Reservation, particularly during the summer months. No objectively determined observations, measurements, or summaries pertaining to dust devil characteristics at Hanford have been compiled. However, investigators utilizing specially instrumented grids and other techniques have determined various characteristics of dust devils in desert-type areas. Since the Hanford area is also a desert-type area, the Hanford dust devils would exhibit some degree of similarity to these others.

The following definitions have been extracted verbatim from the Glossary of Meteorology,[17] American Meteorological Society, 1959:

> dust devil--A well-developed dust whirl; a small but vigorous whirlwind, usually of short duration, rendered visible by dust, sand, and debris picked up from the ground. Diameters range from about 10 feet to greater than 100 feet; their average height is about 600 feet, but a few have been observed as high as several thousand feet. They have been observed to rotate anticyclonically as well as cyclonically. (Dust devils are best developed on a hot, calm afternoon with clear skies in a dry region when intense surface heating causes a very steep lapse rate of temperature in the lower few hundred feet of the atmosphere.)

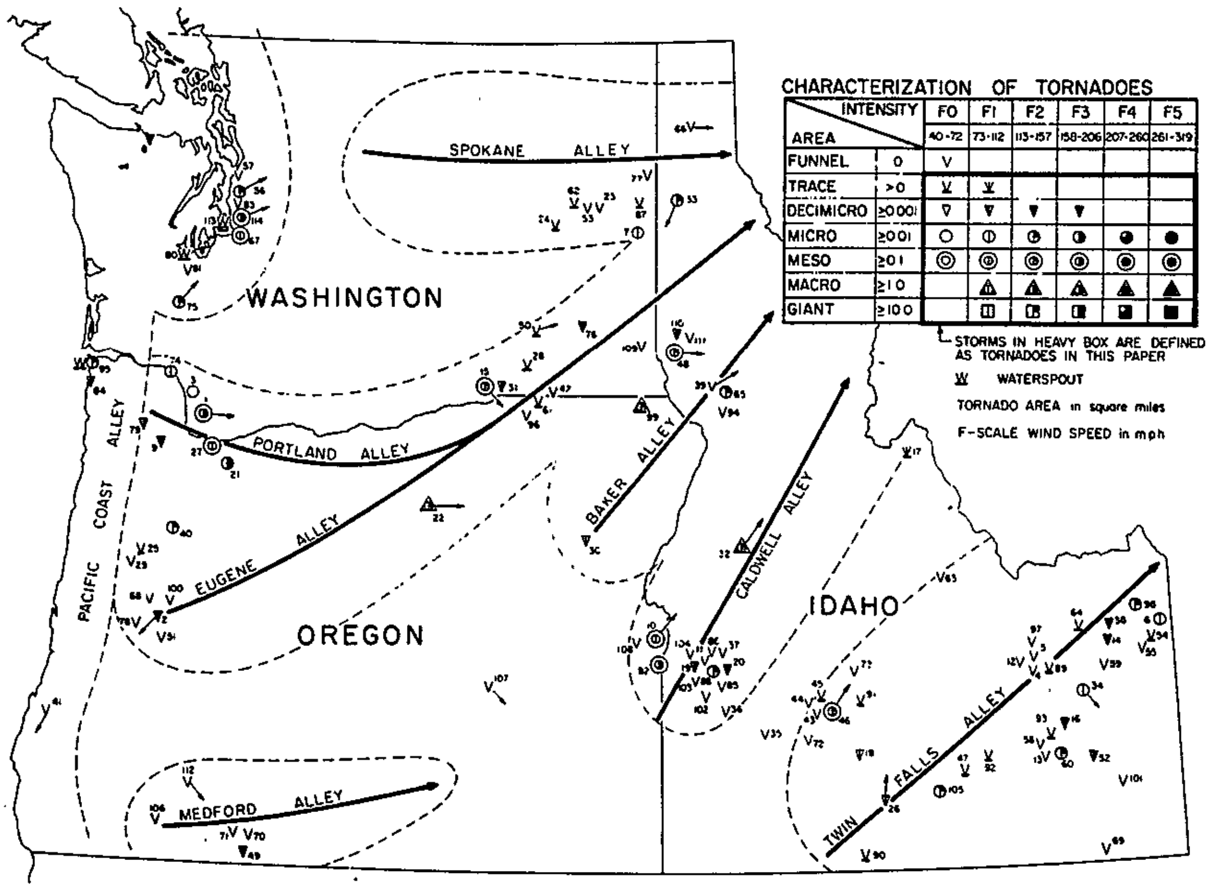

FIGURE II.3-E-16 DISTRIBUTION OF CHARACTERIZED TORNADOES IN 20-YEAR PERIOD, 1950-1969

dust-devil effect--In atmospheric electricity, a rather sudden and short-lived change of the vertical component of the atmospheric electric field that accompanies passage of a dust devil near an instrument sensitive to the vertical gradient. Such changes may be either positive or negative and the charge is probably produced by triboelectrification.

The following has been extracted from a report[18] from Lawrence Radiation Laboratory, 1969:

"Lifetimes vary from a few seconds to nearly 20 minutes, most lasting under two minutes.[19] Ives[20] observed an exceptional example during construction of a large railroad embankment near Sonora: 'In midmorning, a large dust devil suddenly appeared at the end of the embankment, and removed therefrom approximately one cubic yard of sand per hour for four hours. Erosion was halted, and the dust devil broken up, by parking a bulldozer at the end of the fill.'

Dust devils depend directly on the availability of heated boundary-layer air and dissipate quickly if this fuel is removed. The dust columns tend to meander across the desert floor at the prevailing wind speed. However, observers[19] have detected an apparent critical wind speed above which dust devil activity decreases, probably due to destruction of the heated boundary layer by increased vertical mixing and shearing of the vortices near the ground. The vertical velocities near the ground can be appreciable; Ives[20] made an early estimate of these by measuring the terminal velocities of small animals sometimes lifted by dust devils."*

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* In his amusing account Ives notes that the kangaroo rat (terminal velocity ~25 mph) is "apparently unhurt after landing, although usually very angry," whereas a jackrabbit (terminal velocity ~35 mph) is "stunned and internally injured."

More detailed measurements of dust devil velocity, pressure and temperature fields have been made. The results include tangential velocities approaching 15 m/sec, vertical velocities of ten m/sec (at seven feet), and maximum radial velocities of about five m/sec. Commonly, between the environment and the core is a pressure drop in excess of 2 millibars and a temperature increase of 4°C or more. Recent observation results have been developed into a quantitative dust devil model.[21,22] Over 1119 dust devils were observed at close range during a study conducted in the Mojave Desert of Southern California.[23] Maximum horizontal wind speeds up to 34.2 km/hr and vertical wind speeds up to 7.2 km/hr were recorded. A 1947 investigation[20] reported velocities up to 180 km/hr. In a study conducted in the desert of the White Sands Missile Range in New Mexico,[24] wind speeds up to 32 knots and pressure drops of 2.2 millibars were reported.

Hanford dust devils most likely have similar characteristics.

II.3-E.4.4 Hurricanes

The region of the Hanford site is not known to have experienced any hurricanes.

II.3-E.5 Miscellaneous Phenomena and Precipitation

II.3-E.5.1 Thunderstorms

A thunderstorm day is one in which thunder is heard. If a thunderstorm begins in the late evening and lasts past midnight, two thunderstorm days are noted even though only one storm event has occurred. Similarly, even though two or more distinct thunderstorms occur in a day--and this sometimes happens--only a single thunderstorm day is counted.[25] Thunderstorms may occur during any month of the year in the Hanford Reservation area. Although the tabulation below shows zero for the months November through January, the summary period[1] ended in 1970 and a thunderstorm did occur on December 22, 1971. In Richland, about 25 miles southeast of the HMS, one occurred on January 18, 1953. However, the thunderstorm season essentially includes only the months April through September. Although the average is 11 days per year, the number has varied from 3 to 23. In June 1948 there were 8 thunderstorm days during the month, and this record was repeated in August 1953.

Although severe thunderstorms are rare,[1] lightning strikes have occasionally ignited grass fires which have burned thousands of acres of Hanford Reservation land and have resulted subsequently in considerable wind erosion of soil. The most notable of these occurrences were in August 1961, July 1963, July 1970, and August 1973.

THUNDERSTORM DAYS: 1945-1970[1]

	J	F	M	A	M	J	J	A	S	O	N	D	SUM
Total	0	1	7	18	53	64	46	54	24	5	0	0	272
Average	0	#	1	1	2	3	2	2	1	#	0	0	12
% of Total	0	#	3	7	19	23	17	20	9	2	0	0	100

- less than 0.5

II.3-E.5.2 Hail

Hail was reported at the HMS on 14 days or 5% of the days when thunderstorms were reported.[1] The monthly distribution of days on which hail occurred is as follows:

	J	F	M	A	M	J	J	A	S	O	N	D	TOTAL
Number	0	1	1	4	2	1	2	2	1	0	0	0	14
% of Total	0	7	7	30	14	7	14	14	7	0	0	0	100

The hail ranged in size from 0.2 to 0.3 inch in all but two of the available reports. The exceptions were May 26, 1954, and July 1, 1955, when the size reported was 0.4 inch.

Precipitation was not measured during 1945 and 1946, years in which 26 thunderstorm days occurred. There were 246 days during the period 1947-1970 when precipitation was measured. The daily precipitation distribution during these days was as follows:

Amount - Inches	Number of Cases	% of Total
None or trace	110	45
0.01 - 0.10	87	35
0.11 - 0.25	29	12
0.26 - 0.50	15	6
>0.50	5	2
	246	100

The record for rainfall intensity during a thunderstorm is 0.55 inch in 20 minutes (1.65 inches per hour) on June 12, 1969. This storm included hailstones of 1/4 inch diameter. Blowing dust or dust was reported on 16 thunderstorm days and both hail and blowing dust or dust on 6 days.[1]

Peak gust data are not available for the 50, 200, and 400-foot tower levels prior to 1952. The speed classification of peak gusts on the 185 thunderstorm days occurring during the period 1952-1970 is as follows:[1]

mph	Number of Cases 50 Feet	Number of Cases 200 Feet	Number of Cases 400 Feet	% of Total 50 Feet	% of Total 200 Feet	% of Total 400 Feet
<21	18	9	5	10	5	3
21 - 30	75	45	42	40	24	23
31 - 40	63	80	73	34	43	39
41 - 50	23	34	46	12	19	25
51 - 60	4	11	12	2	6	6
61 - 70	1	4	5	1	2	3
>70	1	2	2	1	1	1
	185	185	185	100	100	100

II.3-E.5.3 Lightning

A technique for estimating lightning stroke frequency based on the commonly observed climatological statistic, thunderstorm days, has been developed.[26]

The annual number of discharges N_{yh} to a structure is given by:

$$N_{yh} = \sigma_{yg} A_a F_T$$

where σ_{yg} is the frequency of ground strikes of lightning, A_a is the "attractive area" of a structure and F_T is a factor which accounts for the triggering effect of high structures on lightning. σ_{yg} is a function of thunderstorm frequency and the ratio of innocuous cloud-to-cloud strokes to the potentially damaging cloud-to-ground strikes, a function of latitude ratio. A_a is a function of the height of the structure being considered.* F_T is considered negligible, i.e., 1.0 for structures less than 100 m in elevation.

Use of this technique resulted in the computation of an annual lightning strike frequency of 0.022 or one strike per 46 years for a structure with dimensions of 30 x 35 m and a height of about 10 m, with a thunderstorm-day frequency of 11 per year.[1] (This frequency could be somewhat less if there were obvious protrusions such as taller structures or trees in the vicinity. Such protrusions distort the surface of equal electrical potential gradients in the atmosphere and tend to attract lightning strikes.) A similar computation was made for the 122 m Hanford Meteorology Station which resulted in an annual lightning strike frequency of 0.225, or one strike every 4.44 years. The "reasonableness" of this technique can be adjudged by the fact that three strikes on this tower have been confirmed during its 30-year existence (bearing in mind that all strikes may not have been observed).

II.3-E.5.4 Glaze

Glaze is a coating of ice, generally clear and smooth but with some air pockets, formed on exposed objects at temperatures below or slightly above 32°F by the freezing of super-cooled drizzle or raindrops. Glaze is denser, harder, and more transparent than either rime or hoarfrost.[17] Although the record shows an average of 7 glaze days per year,[1] many of these cause little or no

* In the case of towers at the summits of sharply peaked mountains, the effective height is substantially greater than the actual height of the structure.[26]

inconvenience to the public. Two outstanding exceptions occurred on February 11-12, 1954, and on November 23-24, 1970. There was serious disruption to area traffic in each instance, although there was no known damage to transmission lines. In each instance, rising temperatures soon melted the ice.

II.3-E.5.5 Fog

Although observed in every month of the year at HMS, fog is essentially a seasonal phenomenon, with 95% observed during the months November through February. Inclusion of March and October fog would increase this percentage to 99.7. Tables II.3-E-11 and II.3-E-12 summarize the statistics on fog occurrence at HMS.[1] Because of the higher availability of moisture in the vicinity of the Columbia River, both the frequency and persistence of fog in that area is anticipated to be somewhat greater than at the HMS.

TABLE II.3-E-11

AVERAGE NUMBER OF DAYS OF FOG AT HMS

	Based on all Available Data from 1945 to 1970												
	J	F	M	A	M	J	J	A	S	O	N	D	Y
Fog[a]	9	6	1	(c)	(c)	(c)	(c)	(c)	(c)	2	8	12	38
Fog, dense[b]	6	3	1	(c)	(c)	0	0	(c)	(c)	1	5	8	24

(a) All fog regardless of visibility
(b) Visibility 1/4 mile or less
(c) Less than 1/2 day

TABLE II.3-E-12

TOTAL DURATION[a] AND MAXIMUM PERSISTENCE OF FOG AT THE HMS TABULATED IN HOURS FOR THE PERIOD 1945-1970

ALL FOG (VIZ 0-6 MILES)	AVG TOTAL DURATION	MAX TOTAL DURATION	YEAR	MIN TOTAL DURATION	YEAR	AVG DURATION PER DAY OF OCCURRENCE	MAX. PERSISTENCE[c]	YEAR
JAN	68.3	193.4	1965	0	1949	7.2	58.1	1955
FEB	36.4	206.2	1963	0	1967	6.2	58.0	1963
MAR	4.4	20.6	1951	0	1968+	3.1	12.2	1949
APR	0.3	2.8	1950	0	1970+	1.4	2.8	1950
MAY	0.3	2.7	1958	0	1970+	1.2	2.7	1958
JUNE	#	0.5	1948	0	1970+	0.5	0.5	1948
JULY	#	0.7	1966	0	1970+	0.7	0.7	1966
AUG	#	1.0	1959	0	1970+	1.0	0.7	1959
SEPT	0.3	5.5	1957	0	1970+	2.0	2.6	1957
OCT	7.6	63.6	1962	0	1970+	3.9	39.0	1962
NOV	55.4	148.0	1952	1.0	1960	6.8	65.4	1963
DEC	105.4	193.8	1947	6.5	1968	8.7	72.3	1947
Y	278.4	462.5[a]	1964-65	147.7[b]	1948-49	7.0	72.3	1947-48
DENSE FOG (VIZ 1/4 MI OR LESS)								
JAN	20.4	52.4	1955	0	1949	3.4	15.0	1953
FEB	12.7	86.7	1963	0	1967+	3.8	16.7	1963
MAR	1.8	7.8	1949	0	1968+	2.2	5.0	1961
APR	0.1	1.8	1955	0	1970+	1.8	0	----
MAY	0.1	1.6	1958	0	1970+	1.6	1.6	1958
JUNE	0	0	----	0	----	0	0	----
JULY	0	0	----	0	----	0	0	----
AUG	#	1.0	1959	0	1970+	1.0	0.7	1959
SEPT	0.1	3.2	1957	0	1970+	3.2	1.4	1957
OCT	3.1	35.2	1962	0	1970+	3.1	15.8	1962
NOV	21.1	71.4	1952	0	1960	4.1	20.6	1963
DEC	42.0	119.8	1947	1.3	1968	5.4	47.0	1957
Y	101.4	201.5[a]	1962-63	47.3[b]	1948-49	4.2	47.0	1957-58

(a) TOTAL DURATION DENOTES TOTAL NUMBER OF HOURS AND TENTHS OF HOURS IN WHICH FOG IS OBSERVED.

(b) DENOTES LESS THAN 0.05 HOUR

(c) DENOTES THE GREATEST NUMBER OF HOURS IN A SEASON

No fog observations have been regularly recorded for the slopes and the crest of Rattlesnake Mountain. However, because of Rattlesnake's higher elevation, one would not expect any HMS fog statistics to be descriptive of fog events there. Crest clouds (a type of standing cloud which forms along a mountain ridge, either on the ridge or slightly above and to leeward of it, and remains in the same position relative to the ridge)[25] have been observed frequently on the Hanford Reservation. At other times when most areas of the Hanford Reservation were experiencing fog and/or low stratus clouds, the crest of Rattlesnake Mountain was clear and above the fog.

II.3-E.5.6 Air Pollution Potential (APP)

Consideration of the general weather parameters indicates a significantly high average annual APP over southeastern Washington. The mean annual mixing depth[27] in this area is about 450 m and for July about 2000 m. A significantly high frequency of low-level inversion[28] in winter over this area is indicated on the order of 43% with bases below 150 m. The occurrence of very stable and moderately stable conditions between the surface and 60 m in winter at the HMS is 66.5%.[1]

Stagnation[29] is defined as "the persistence of a given volume of air over a region, permitting an abnormal buildup of pollutants from sources within the region." By defining stagnation as an uninterrupted period of daily average wind speed of 5.0 mph or less and/or a peak gust of 15 mph or less, a 15-year summary[3] of stagnation periods covering the months November through February (1947-48 through 1961-62) has been accomplished. The two most notable stagnation periods experienced during this time occurred in November and December, 1952. The first period was from November 15 to December 3 (19 days). Then, after 5 days of ventilation, stagnation set in again on December 9 and lasted through December 28 (20 days). Average wind speeds during the two periods were, respectively, 2.6 and 2.9 mph. Eleven days during the first period and eight during the second had peak gusts under 10 mph. One day during the first period and two during the second had average speeds less than 1.0 mph with peak "gusts" of 4 mph. There were 13 days of fog in each period.

Figure II.3-E-17 summarizes the preceding investigation. Examination of this figure reveals that although stagnation lasting for 20 days can be expected only one season in 20, a 10-day stagnation period can be expected every other season. Only one season in three will fail to produce a stagnation period of at least 8 days.

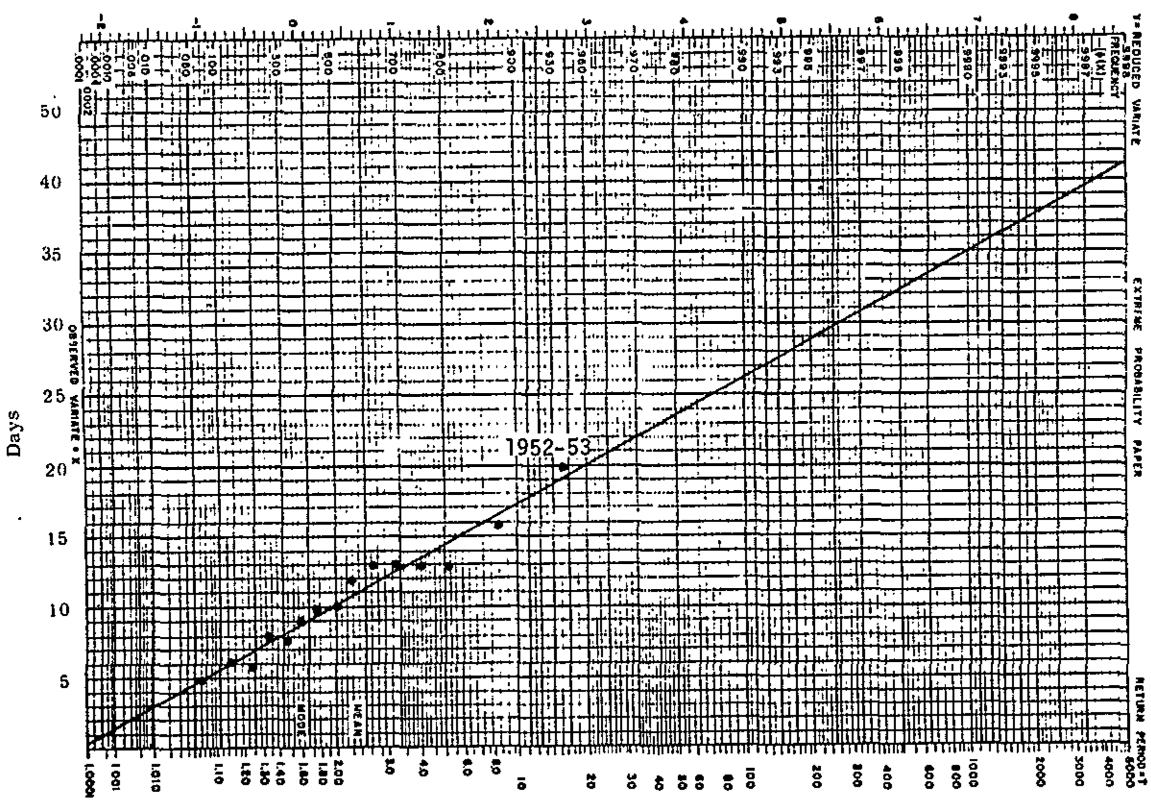


FIGURE II.3-E-17 SEASONAL MAXIMUM PERSISTENCE OF STAGNATION, 1947-48 THROUGH 1961-62

The major cause of air pollution in the area is dust occurring during windy periods. The most significant sources are cultivated fields in the surrounding area. Dust or blowing dust occurs on an average of 6 days per year.[1]

II.3-E.5.7 Sky Cover and Solar Radiation

The number of clear, partly cloudy, and cloudy days at the HMS itemized in Table II.3-E-13 come from assigning each day to one of three categories in accordance with the following:[1]

Category	Average Sky Cover (Tenths from Sunrise to Sunset)
Clear	0 - 3
Partly Cloudy	4 - 7
Cloudy	8 - 10

About 200 days annually are sunny days at Hanford (the sum of the number of clear days and partly cloudy days).

Table II.3-E-14 presents solar radiation data measured at the HMS.[1]

TABLE II.3-E-13

HMS MONTHLY AND HOURLY SKY COVER AVERAGES STATISTICS ON CLEAR, PARTLY CLOUDY, AND CLOUDY DAYS

HOUR (PST)	TABULAR VALUES BASED ON THE PERIOD 1957-70												
	J	F	M	A	M	J	J	A	S	O	N	D	Y
00	7.1	6.0	5.2	5.1	4.6	4.4	2.4	2.5	3.4	4.5	6.6	7.4	4.9
01	7.1	6.1	5.4	5.2	4.6	4.1	2.2	2.5	3.4	4.5	6.7	7.5	4.9
02	7.1	6.1	5.4	5.3	4.5	4.0	2.1	2.4	3.5	4.7	6.6	7.5	4.9
03	7.3	6.2	5.4	5.2	4.8	4.5	2.4	2.4	3.5	4.8	6.4	7.4	5.0
04	7.4	6.3	5.5	5.5	5.2	4.7	2.5	2.8	3.5	4.8	6.5	7.5	5.2
05	7.4	6.7	5.7	6.0	5.6	5.0	2.7	3.3	4.3	5.0	6.6	7.8	5.5
06	7.5	7.2	6.3	6.2	5.6	4.9	2.6	3.4	4.5	5.5	6.8	7.8	5.7
07	8.1	7.5	6.6	6.3	5.6	4.8	2.7	3.3	4.4	5.9	7.5	8.3	5.9
08	8.3	7.6	6.8	6.3	5.4	4.7	2.5	3.2	4.3	5.8	7.7	8.4	5.9
09	8.2	7.6	6.7	6.3	5.5	4.8	2.4	3.0	4.2	5.8	7.6	8.3	5.9
10	8.2	7.5	6.6	6.4	5.6	5.0	2.5	3.2	4.3	5.8	7.4	8.5	5.9
11	8.1	7.3	6.8	6.5	5.8	5.3	2.6	3.2	4.3	5.8	7.4	8.4	5.9
12	8.1	7.4	6.9	6.7	6.0	5.2	2.8	3.3	4.3	6.0	7.6	8.3	6.0
13	8.1	7.4	7.0	7.0	6.2	5.3	2.9	3.4	4.4	6.2	7.7	8.2	6.1
14	8.0	7.4	7.0	7.0	6.1	5.3	3.0	3.5	4.4	6.3	7.6	8.1	6.1
15	8.0	7.4	6.9	6.9	6.3	5.4	3.1	3.6	4.4	6.4	7.5	8.1	6.2
16	8.1	7.4	6.9	7.0	6.4	5.6	3.2	3.7	4.4	6.4	7.3	8.0	6.2
17	7.9	7.2	6.9	6.8	6.2	5.4	3.2	3.6	4.4	6.2	7.1	7.8	6.0
18	7.5	6.7	6.7	6.7	6.1	5.4	3.1	3.4	4.4	5.9	6.9	7.6	5.9
19	7.4	6.3	6.3	6.4	6.1	5.3	3.2	3.2	4.2	5.6	6.6	7.6	5.7
20	7.3	6.2	5.9	6.0	5.8	5.1	3.0	3.1	3.9	5.4	6.5	7.5	5.5
21	7.1	6.2	5.7	5.6	5.2	4.8	2.8	2.8	3.8	4.9	6.6	7.4	5.2
22	7.2	6.3	5.4	5.4	4.7	4.3	2.4	2.7	3.6	4.8	6.5	7.3	5.0
23	7.0	6.2	5.3	5.2	4.5	4.0	2.3	2.6	3.4	4.6	6.7	7.2	4.9
AVG	7.6	6.9	6.2	6.1	5.5	4.9	2.7	3.1	4.0	5.5	7.0	7.8	5.6

AVERAGE SKY COVER (SUNRISE TO SUNSET) AND NUMBER OF DAYS CLEAR, PARTLY CLOUDY AND CLOUDY 1946-70

	SKY COVER (SCALE 0-10)					NUMBER OF CLEAR DAYS					PARTLY CLOUDY DAYS	NUMBER OF CLOUDY DAYS				
MONTH	AVG	RECORD. GREATEST	YEAR	RECORD LEAST	YEAR	AVG	RECORD GREATEST	YEAR	RECORD LEAST	YEAR		AVG	RECORD GREATEST	YEAR	RECORD LEAST	YEAR
JAN	7.8	9.0	1969	4.3	1949	3	13	1949	0	1955+	6	22	27	1969+	6	1949
FEB	7.4	8.9	1961	5.9	1964	5	9	1968+	1	1969+	5	18	26	1958	10	1951+
MAR	6.7	7.9	1950	4.9	1965	7	12	1965+	2	1961+	8	16	22	1968	7	1948
APR	6.4	8.1	1963	3.7	1951	6	18	1951	1	1963	10	14	21	1963	3	1949
MAY	5.8	7.7	1960	4.5	1949	8	14	1953	2	1960	11	12	19	1960	3	1949
JUNE	5.2	7.0	1950	2.8	1961	10	21	1961	3	1966	10	10	15	1957	0	1949
JULY	2.7	4.5	1955	0.9	1953	20	27	1953	14	1955	7	4	8	1955	0	1967+
AUG	3.3	5.9	1968	0.6	1955	19	30	1955	11	1968	7	5	13	1968	0	1969+
SEPT	4.1	6.1	1959	2.5	1950	15	21	1967	8	1969	7	8	13	1969	2	1952+
OCT	5.9	7.7	1950	3.9	1952	10	16	1953	3.	1950+	7	14	18	1956+	3	1946
NOV	7.5	9.0	1965	6.2	1957	5	10	1957	1	1965+	5	20	24	1965+	12	1948
DEC	8.1	9.2	1962	6.8	1954	3	7	1954	0	1947	5	23	28	1962	14	1946
Y	5.9	6.4	1966	5.1	1949	111	134	1967	85	1966	88	166	181	1969+	151	1967

TABLE II.3-E-14

HMS AVERAGE HOURLY AND DAILY SOLRAD TOTALS (LANGLEYS)
BASED ON THE PERIOD 1957-70

HOUR BEGINNING (PST)	J	F	M	A	M	J	J	A	S	O	N	D	Y
04	0	0	0	(a)	1.1	2.4	1.3	0.1	0	0	0	0	0.4
05	0	0	(a)	2.4	8.5	11.5	9.8	4.3	0.7	(a)	0	0	3.1
06	0	0.1	2.8	11.9	20.9	24.9	23.3	16.0	8.2	2.1	0.1	0	9.2
07	0.4	3.0	12.4	25.4	35.0	39.4	38.7	30.3	21.2	10.8	2.9	0.4	18.4
08	4.8	11.1	24.0	38.6	47.8	52.1	53.1	44.6	34.8	22.2	9.8	4.2	29.0
09	11.7	19.8	35.3	49.4	58.0	61.4	63.5	55.5	45.7	31.6	17.0	9.7	38.3
10	17.8	27.8	43.6	56.7	64.2	67.6	71.1	63.0	53.4	38.3	22.0	14.5	45.0
11	21.4	32.4	48.7	58.7	67.2	70.5	74.7	66.0	56.0	41.2	24.0	17.3	48.1
12	21.9	33.1	48.2	57.7	63.7	69.2	73.8	66.1	55.6	39.8	23.0	17.3	47.5
13	18.8	30.0	43.9	52.0	59.7	63.8	69.0	62.7	50.3	33.8	18.9	14.5	43.0
14	13.6	24.1	36.9	45.1	52.8	56.3	61.7	53.5	40.9	24.9	13.0	9.2	36.0
15	6.8	15.6	26.4	34.1	42.1	46.2	50.7	42.2	29.4	14.8	5.6	3.4	26.5
16	1.3	6.0	14.6	22.1	29.4	34.1	37.6	29.0	16.4	5.0	0.6	0.1	16.4
17	0	0.6	4.3	10.4	17.3	21.4	23.1	15.2	5.1	0.4	0	0	8.2
18	0	0	0.1	2.2	6.2	9.8	9.8	4.3	0.4	(a)	0	0	2.8
19	0	0	0	0	0.7	2.6	1.7	0.2	0	0	0	0	0.4
SUM (b)	118.5	203.6	341.2	466.7	574.6	633.2	662.9	553.0	418.1	265.1	136.9	90.6	372.3
AVG (c)	118	200	340	470	571	626	659	551	418	262	135	91	370
HM (d)	135	238	388	526	634	698	700	613	457	299	180	116	385
YEAR	1962	1960	1965	1959 (e)	1970	1960	1969 (e)	1955	1961	1958	1957	1970	1957
LM (f)	88	164	305	374	511	563	588	475	354	227	97	57	357
YEAR	1955	1954	1961	1963	1962	1953	1955	1968	1959	1956	1964	1969	1967

(a) AN AMOUNT TOO SMALL TO MEASURE

(b) AVERAGE DAILY TOTAL BASED ON THE PERIOD 1957-70

(c) AVERAGE DAILY TOTAL BASED ON THE PERIOD 1953-70

(d) HM HIGHEST MONTHLY AND ANNUAL (1953-70)

(e) ALSO IN EARLIER YEARS

(f) LM LOWEST MONTHLY AND ANNUAL (1953-70)

II.3-E.5.8 Precipitation[1]

At the Hanford Meteorology Station average annual precipitation is 6.25 inches. The 3 months November-through-January contribute 42% of this total, while the 3 months July-through-September contribute only 10%. There are only two occurrences per year of 24-hour amounts of 0.50 inch or more, while occurrences of 24-hour amounts of 1.00 inch or more number only four in the entire 25 years of record (1946-1970). One of these was the record storm of October 1-2, 1957, in which rainfall totaled 1.08 inches in 3 hours, 1.68 inches in 6 hours, and 1.88 inches in 12 hours. At the other extreme, there have been 81 consecutive days without measurable rain (June 22-September 10, 1967), 139 days with only 0.18 inch (June 22-November 7, 1967), and 172 days with only 0.32 inch (February 24-August 13, 1968).

About 45% of all precipitation during the months December-through-February is in the form of snow. However, only one winter in eight can expect an accumulation of as much as 6 inches on the ground. The average seasonal number of such days is five, although the 1964-65 winter had 35, 32 of which were consecutive.

Figure II.3-E-18 presents HMS average monthly precipitation data. It can be seen that there is a maximum during the winter months with a secondary maximum occurring in June. Tables II.3-E-15 and II.3-E-16 and Figures II.3-E-19 and II.3-E-20 present various observed and theoretical extreme values of precipitation amounts and intensities during specified time periods. Figure II.3-E-21 presents similar data for depth of snow. Examination of these tables and figures would indicate that a "500-year storm," for example, could result in a greatest depth of snow on the ground on the order of 30 inches.

These precipitation data are considered generally representative of the entire Hanford Reservation except for the ALE area on Rattlesnake Mountain where precipitation may range up to 10 to 15 inches as a result of orographic effects.[30]

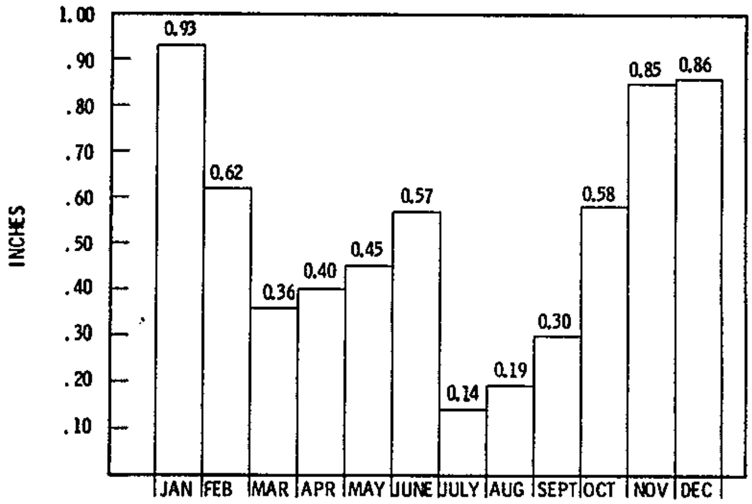


FIGURE II.3-E-18 AVERAGE MONTHLY PRECIPITATION AMOUNTS BASED ON THE PERIOD 1912-1970

TABLE II.3-E-15

PROBABLE DURATION OF VARIOUS PRECIPITATION INTENSITIES AT HANFORD FOR 500-YEAR STORM

Time Period	Amount (Inches)[a]	Intensity (Inches per Hour)[a]
5 minutes	0.5	6.0
10 minutes	0.6	3.6
15 minutes	0.7	2.8
20 minutes	0.73	2.2
30 minutes	0.9	1.8
40 minutes	0.93	1.4
50 minutes	1.00	1.2
60 minutes	1.02	1.02
2 hours	1.22	0.61
3 hours	1.33	0.44
4 hours	1.52	0.38
5 hours	1.70	0.34
6 hours	1.98	0.33
8 hours	1.84	0.23
10 hours	1.96	0.196
12 hours	2.34	0.195
18 hours	2.52	0.14
24 hours	2.47	0.103
1 year	15.60	

(a) Differences in values between tables and figures can be attributed to smoothing errors when graphing the lines.

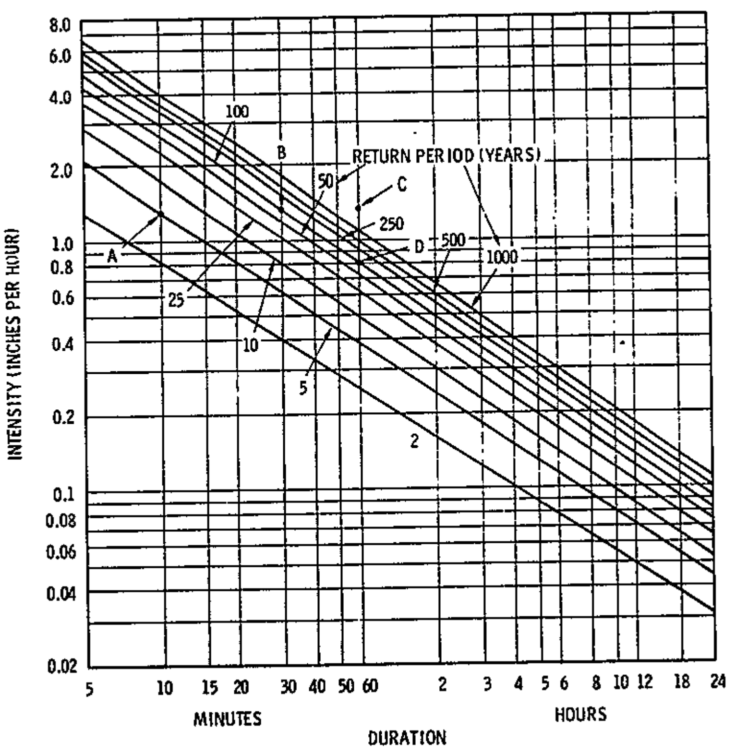
TABLE II.3-E-16

AVERAGE RETURN PERIOD (R) AND EXISTING RECORD (ER) FOR VARIOUS PRECIPITATION AMOUNTS AND INTENSITY DURING SPECIFIED TIME PERIODS AT HANFORD

(based on extreme value analysis of 1947-69 records)

	AMOUNT (INCHES)							INTENSITY (INCHES PER HOUR)						
	TIME PERIOD							TIME PERIOD						
R (YEARS)	20 MIN	60 MIN	2 HRS	3 HRS	6 HRS	12 HRS	24 HRS	20 MIN	60 MIN	2 HRS	3 HRS	6 HRS	12 HRS	24 HRS
2	0.16	0.26	0.30	0.36	0.48	0.62	0.72	0.49	0.26	0.15	0.12	0.08	0.052	0.030
5	0.24	0.40	0.48	0.55	0.77	0.95	1.06	0.72	0.40	0.24	0.18	0.13	0.079	0.044
10	0.37	0.50	0.59	0.67	0.96	1.17	1.28	1.1	0.50	0.30	0.22	0.16	0.098	0.053
25	0.47	0.62	0.74	0.83	1.21	1.45	1.56	1.4	0.62	0.37	0.28	0.20	0.121	0.065
50	0.53	0.72	0.85	0.96	1.40	1.66	1.77	1.6	0.72	0.42	0.32	0.23	0.138	0.074
100	0.60	0.81	0.96	1.07	1.59	1.87	1.99	1.8	0.81	0.48	0.36	0.27	0.156	0.083
250	0.68	0.93	1.11	1.22	1.82	2.13	2.26	2.0	0.93	0.55	0.41	0.30	0.177	0.094
500	0.73	1.02	1.22	1.33	2.00	2.34	2.47	2.2	1.02	0.61	0.44	0.33	0.195	0.103
1000	0.80	1.11	1.33	1.45	2.20	2.55	2.68	2.4	1.11	0.67	0.48	0.37	0.212	0.112
ER	(a)	0.59	0.88	1.08	1.68	1.88	1.91	(a)	0.59	0.44	0.36	0.28	0.157	0.080
		6/12	10/1	10/1	10/1-2	10/1-2	10/1-2		6/12	10/1	10/1	10/1-2	10/1-2	10/1-2
DATE	--	1969	1957	1957	1957	1957	1957	--	1969	1957	1957	1957	1957	1957

(a) NO RECORDS HAVE BEEN KEPT FOR TIME PERIODS OF LESS THAN 60 MINUTES. HOWEVER, THE RAIN GAGE CHART FOR 6-12-69 SHOWS THAT 0.55 INCH OCCURRED DURING A 20-MINUTE PERIOD FROM 1835 TO 1855 PST. AN ADDITIONAL 0.04 INCH OCCURRED BETWEEN 1855 AND 1910 TO ACCOUNT FOR THE RECORD 60-MINUTE AMOUNT OF 0.59 INCH.



TO USE THIS CHART, SELECT ANY DESIRED RAINFALL INTENSITY AND DURATION AND READ FROM THE DIAGONAL LINES THE EXPECTED FREQUENCY OF SUCH INTENSITY AND DURATION. FOR EXAMPLE, RAINFALL INTENSITY OF 1.3 INCHES PER HOUR FOR 10 MINUTES CAN BE EXPECTED TO OCCUR, ON AVERAGE, ONCE EVERY 5 YEARS (POINT A). HOWEVER, SUCH INTENSITY CAN BE EXPECTED FOR 30 MINUTES DURATION ONLY ABOUT ONCE IN 100 YEARS (POINT B). THE RETURN PERIOD FOR THIS INTENSITY FOR 60 MINUTES DURATION IS GREATER THAN 1000 YEARS (POINT C).

THERE ARE, OF COURSE, VARIATIONS IN USE OF THE CHART. SUPPOSE, FOR EXAMPLE, IT IS DESIRED TO FIND THE "100-YEAR STORM" FOR 60 MINUTES. THIS IS 0.8 INCH (POINT D).

FIGURE II.3-E-19 RETURN PERIODS OF RAINFALL INTENSITY AND DURATION (based on the period 1947-69 at HMS)

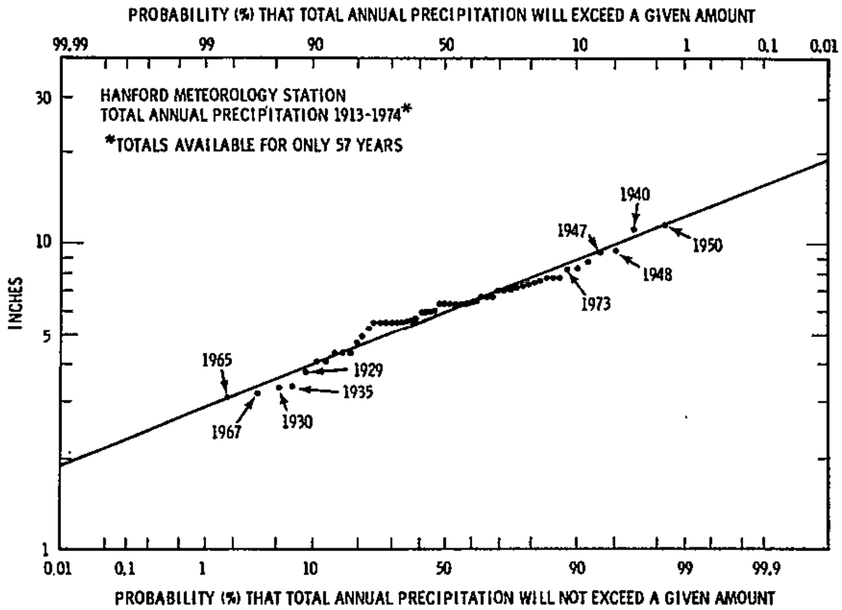


FIGURE II.3-E-20 TOTAL ANNUAL PRECIPITATION PROBABILITY DIAGRAM

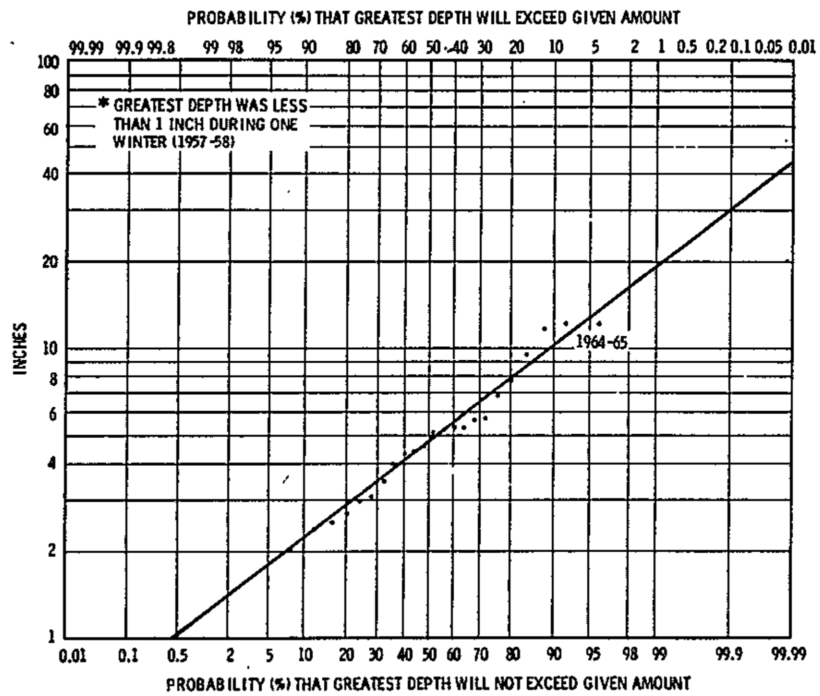


FIGURE II.3-E-21 GREATEST DEPTH OF SNOW ON GROUND DURING 24 OF 25 WINTERS OF RECORD AT HANFORD 1946-47 THROUGH 1969-70

A study[31] on climatic effects of irrigation suggests a 25% increase in local precipitation can be attributed to irrigation in the Southern Columbia Basin Irrigation District. Another study[8] indicates that these conclusions are at variance with most other research where irrigation is shown to have a minimum influence at distances much beyond boundaries of even substantial (40,000 to 50,000 hectares) irrigated blocks. In the latter study no statistically significant difference was found between rainfall at stations inside the Columbia Basin Project and at upstream reference stations. Figure II.3-E-22 presents HMS total annual precipitation and 10- and 15-year moving averages. Total annual precipitation at the HMS has generally decreased between 1950 and 1970 when the Columbia Basin irrigation operation grew from 2876 hectares to 180,732 hectares.[8] This decrease tends to refute the conclusion that an increase in local precipitation can be attributed to irrigation.

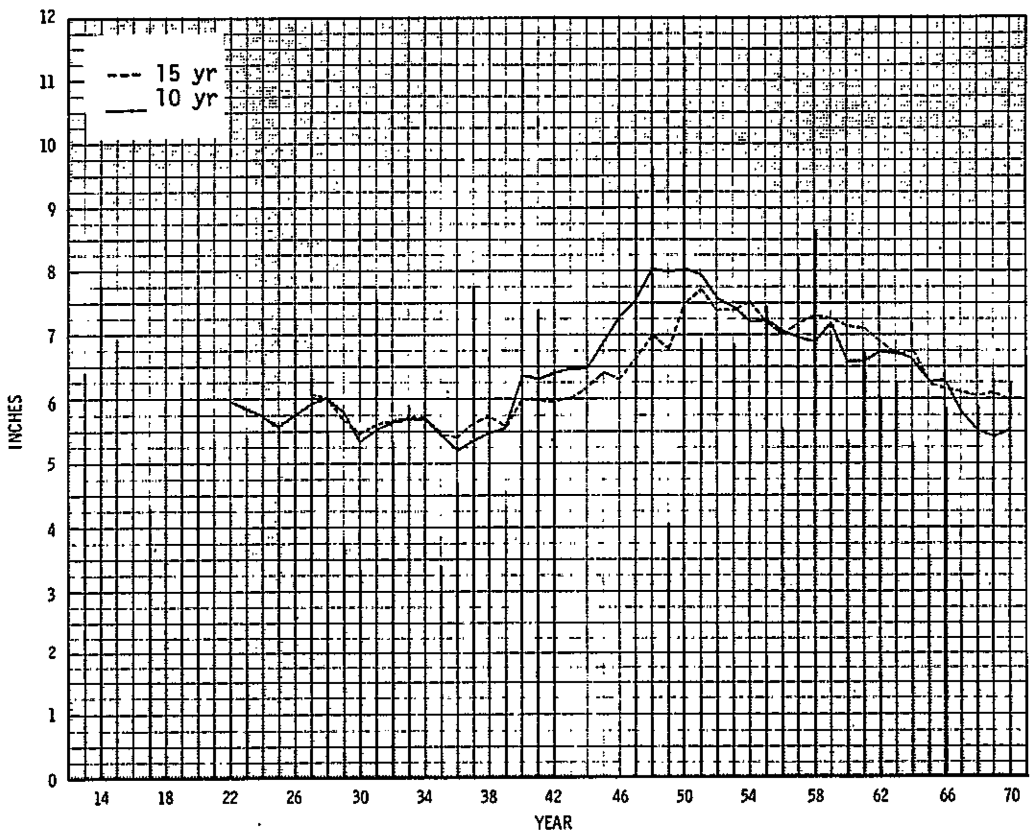


FIGURE II.3-E-22 HMS TOTAL ANNUAL PRECIPITATION (1913-1970) AND 10 and 15 YEAR MOVING AVERAGES

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APPENDIX II.3-F

AQUATIC ECOLOGY

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APPENDIX II.3-F, Part 1

<u>Aquatic Ecology</u>

II.3-F, Part 1 Aquatic Ecology

The dominant aquatic ecosystem on the Hanford Reservation is the Columbia River. The fifth largest river in North America, it has a total length of 1,214 miles from its origin in British Columbia to its entrance into the Pacific Ocean. Numerous dams have been built on the river, with the only free-flowing U.S. section occurring between Priest Rapids Dam and McNary Reservoir. No significant tributaries enter the stream in this section which is mostly contained within the Hanford Reservation. The entire Columbia River is exceptionally clean for a river of its size. The only other natural lotic ecosystem of any size on the Hanford Reservation is Rattlesnake Springs.

Several small lentic sites that are a result of waste discharge effluents are present within the Hanford Reservation. The largest of these is Gable Mountain Pond.

II.3-F.1 The Columbia River

The basic physical and chemical characteristics of the Columbia River were presented in previous sections of this report. Additional nonbiological data as well as comprehensive evaluations of the ecological characteristics of the Columbia River, mainly in the Hanford to McNary Dam section are available.[1-3]

Studies concerned with the various aquatic organisms in the Columbia River, relating mainly to influence of reactor operation, have been conducted for over 25 years; a bibliography with abstracts of these investigations was recently published.[4] The following paragraphs summarize the essential ecological characteristics of the major communities. Figure II.3-F-1 is a simplified diagram of the food-web relationships in selected Columbia River biota and represents probable major energy pathways.

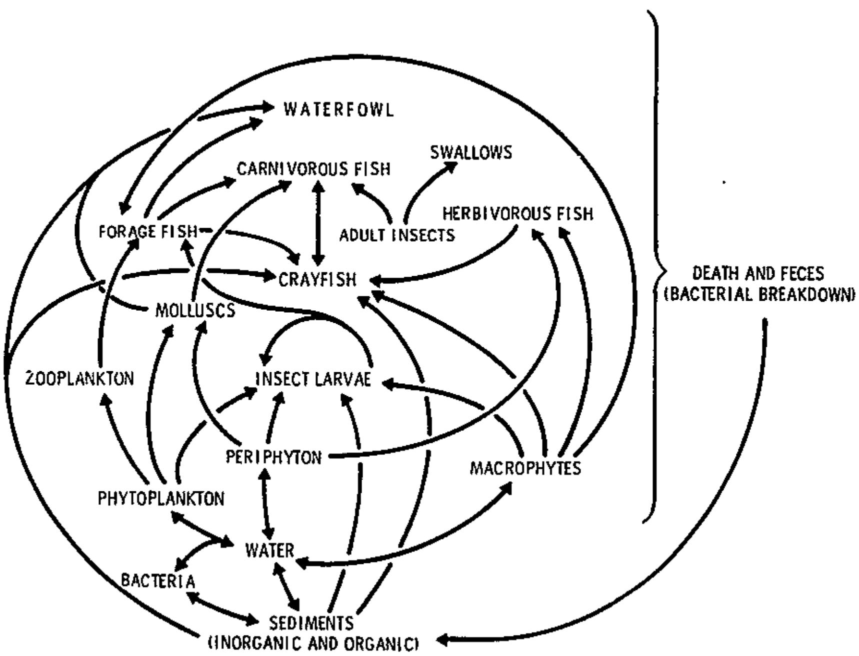

FIGURE II.3-F-1 FOOD WEB OF COLUMBIA RIVER

The Columbia River presents a very complex ecosystem in terms of trophic relationships due to its size, the number of man-made alterations, the diversity of the biota, and the size and diversity of its drainage basin. Streams in general, especially smaller ones, depend greatly upon allochthonous input of organic matter to drive the energetics of the system. Large rivers, particularly the Columbia with its series of lentic reservoirs, contain a significant population of autochthonous primary producers (phytoplankton and periphyton) which contribute the basic energy needs. The dependence of the free-flowing Columbia River in the Hanford stretch upon an autochthonous food base is reflected by the faunal constituents, particularly the herbivores in the second trophic level. Filterfeeding insect larvae such as caddis fly larvae, Hydropsyche, and periphyton grazers such as limpets and some mayfly nymphs are typical forms present. Shredders and large detrital feeders (such as the large stonefly nymphs) which are typical of smaller streams are absent. The presence of large numbers of the herbivorous suckers also attests to the presence of a significant periphytic population. Carnivorous species are numerous, as would be expected in a system of this size.

II.3-F.1.1 Phytoplankton

Diatoms are the dominant algae in the Columbia River, usually representing over 90% of the population. The main genera include Fagilaria, Asterionella, Melosira, Tabellaria, and Synedra. Lentic forms that originate in the impoundments behind the upstream dams are dominant in the Hanford section of the river. The phytoplankton also contain a number of species derived from the periphyton or sessile algae community. This is particularly true of the Columbia River in the Hanford area because of the fluctuating daily water levels. Periphytic algae exposed to the air for part of the day may dry up and then become detached and suspended in the water when the river level rises again. Peak biomass of net phytoplankton is about 2.0 g dry wt/m^3 in May while winter values are less than 0.1 g dry wt/m^3.[5] Figure II.3-F-2 illustrates the seasonal fluctuations in plankton biomass. A spring increase with a second pulse in late summer and autumn was observed in the Hanford section of the Columbia River in previous studies.[6,7] The spring pulse is probably related to increasing light and warming of the water rather than to availability of nutrients. The coincident decrease of PO_4 and NO_3, essential nutrients for algae growth, may be partially related to uptake by the increasing phytoplankton populations but is also highly influenced by the dilution of these nutrients by the increased flows due to high run-off at this time. The degree of dilution depends upon the concentration of these nutrients in the run-off waters. However, these nutrients do not decrease to concentrations limiting to algae growth at any time of the year. Green and blue-green algae occur mainly in the warmer months, but in substantially fewer numbers than the diatoms.

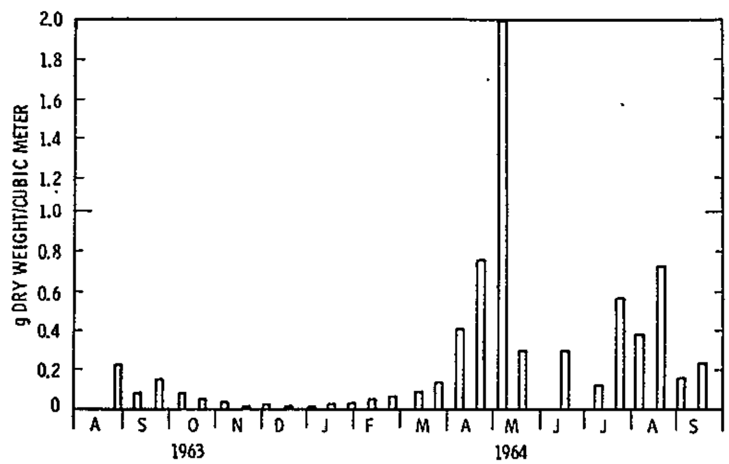

FIGURE II.3-F-2 SEASONAL FLUCTUATION OF PLANKTON BIOMASS

II.3-F.1.2 Periphyton

Periophytic communities develop on suitable solid substrates wherever sufficient light occurs for photosynthesis. Dominant diatom genera include Melosira and Gomphonema and in spring and summer luxuriant growths of the filmentous green algae Stigeoclonium and Ulothrix occur. Net Production Rate (NPR), as measured from 14 day colonization of artificial substrates, varied from 0.07 mg dry wt/cm^2/day in August to less than 0.01 mg dry wt/cm^2/day in December and January.[8] Figure II.3-F-3 shows the seasonal pattern of NPR and represents the 14 day growth on clean glass slides and not the increment on an established community. NPR was highly correlated with solar energy and chlorophyll a concentration on the slides during the two week exposure. The high correlation with chlorophyll a is consistent with the fact that closest relationships between pigment content and productivity are usually found only during periods of rapid growth. The colonization conditions obtained in these studies began from a bare surface, and after two-weeks the communities were probably still in the log-growth phase. Correlations among biomass measurements were highest between dry weight and ash weight, due mainly to the high population of diatoms with silica frustules.

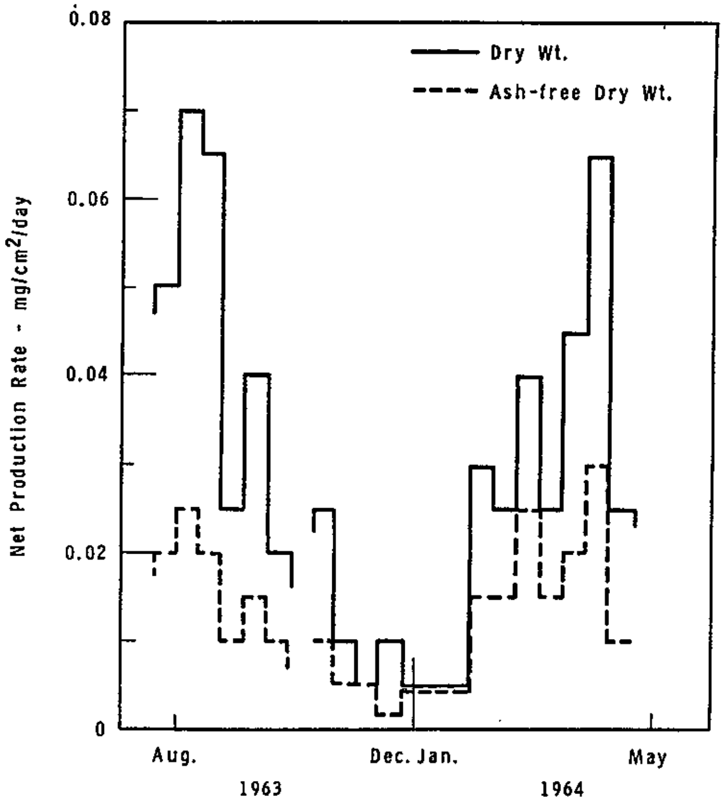

FIGURE II.3-F-3 SEASONAL FLUCTUATION OF NET PRODUCTION RATE OF PERIPHYTON

II.3-F.1.3 Macrophytes

Emergent macrophytic vegetation is extremely sparse and is usually found in slackwater areas. Rushes (Juncus) and sedges (Carex) occur in flooded areas, particularly after high-water levels recede. These areas are located above 100-K, below 100-D, and in the sloughs between 100-H and 100-F, below 100-F, and near the old Hanford townsite.

II.3-F.1.4 Zooplankton

In the Hanford stretch of the Columbia River, zooplankton populations are generally sparse and associated with benthic deposits in slack water areas near the edge of the river; cladocerans are more abundant than copepods.[9] Quantitative data showed a pronounced spring pulse of 260,000 organisms/ft^2. Alona rectangula, A. affinis, and Chydorus sphaericus predominate in spring, fall, and winter. Sida crystallina and Eurycercus lemallatus are most abundant in summer. Twenty-four species of Cladocera and Copepoda have been identified in McNary Reservoir.[10] This reservoir receives water from the Yakima, Snake, and Walla Walla Rivers as well as from the Columbia, all of which may contribute to the zooplankton population.

II.3-F.1.5 Benthos

Benthic biota consist of organisms which are either attached to or live closely associated with the substrate. Dominant organisms presently found in the free-flowing Columbia include insect larvae, sponges, molluscs, flatworms, leeches, crayfish, and oligochaetes. The daily fluctuating water levels, due to the manipulation of flow by an upstream hydroelectric dam, have destroyed a part of this fauna in the littoral zone. Near the old Hanford townsite, midge larvae (Chironomidae) and caddis fly larvae (Trichoptera) are the most numerous benthic organisms, averaging 121 and 208 organisms/ft^2, respectively.[1] Caddis fly larvae and molluscs (Mollusca) are predominant in terms of biomass, averaging 2.24 and 1.23 g wet wt/ft^2, respectively. Total benthic organisms averaged 375/ft^2 and 3.59 g wet wt/ft^2 during 1951-52. These figures are approximations of these populations due to the difficulty in sampling all of the bottom in a large river such as the Columbia. Sampling was restricted to the shallow shoreline, and even there variations between replicate samples were sometimes greater than seasonal variations.

II.3-F.1.6 Fish

Thirty-nine species of fish (Part 2 of this appendix) have been identified in the Hanford area of the Columbia River.[4,11] Of the many species of fish in the river, the anadromous salmon and steelhead trout are of greatest economic importance. The Hanford reach of the Columbia serves as a migration route to and from upstream spawning grounds for chinook, sockeye, and coho salmon and for steelhead trout. Both fall chinook salmon and steelhead trout also spawn in the Hanford reach of the river. Population estimates of the locally spawning chinook salmon are made annually by means of aerial surveys and enumeration of the number of salmon nests (redds) in the reach of river from Richland to Priest Rapids Dam (Table II.3-F-1). For the period 1947 to 1972 the average number of chinook salmon spawners was almost 9500 fish, with a range of 450 to 31,600.[12] Since 1962, the local fall chinook salmon spawning population represents 15 to 20% of the total fall chinook escapement to the river.[13] This recent increase in relative importance of the Hanford reach for chinook spawning may result from the destruction of other mainstem spawning grounds by river impoundments.

The chinook juveniles move through the Hanford reach of the Columbia in two age classes, young-of-the-year and yearlings. The young-of-the-year in particular inhabit the areas near shore where they feed as they move downstream. They are present from late winter through midsummer, with greatest numbers in April, May, and June.

TABLE II.3-F-1

NUMBER OF SPAWNING FALL CHINOOK SALMON AT HANFORD, 1947-1973
(population estimate based on 7 fish per redd)

Year	No. of Redds[a]	Population Estimate
1947	240	1680
48	785	5500
49	330	2310
50	316	2210
51	314	2200
52	539	3770
53	149	1040
54	157	1100
55	64	490
56	92	640
57	872	6100
58	1485	10400
59	281	1970
60	295	2070
61	939	6570
62	1261	8830
63	1303	9120
64	1477	10300
65	1789	12500
66	3101	21700
67	3267	22900
68	3560	24900
69	4508	31600
70	3813	26700
71	3600	25200
72	876	6130
73	2965	20800

(a) Redd counts obtained by aerial surveys

Average annual steelhead spawning population estimates for the years 1962-1971 are about 10,000 fish.[14] The annual estimated 1963-1968 sport catch in the reach of river from Ringold, just downstream from the Hanford site boundary, to the mouth of the Snake River, a distance of about 30 miles, was approximately 2700 fish.

The shad, another anadromous species, may also spawn in the Hanford reach of the river. Young-of-the-year of this fish are collected during the summer. The upstream range of the shad has increased since the mid 1950's, possibly as the result of increased impoundment of water in the lower and middle river. In 1956 fewer than ten adult shad ascended McNary Dam; in 1966 about 10,000 passed upstream. The whitefish are resident in the Hanford reach of the river and support a winter sport fishery. During the period of maximum plutonium production reactor operation, upstream movement of whitefish and other resident species was demonstrated by the capture of fish containing greater than background levels of radionuclides at Priest Rapids Dam, upstream of the Hanford Reservation.

Other game species such as sturgeon, smallmouth bass, crappie, and sunfish are also fairly abundant in the Hanford section of the Columbia. These populations are enhanced by the prohibition of fishing and public access to most of the river within the Hanford Reservation.

Population estimates have not been made of resident coarse fishes (such as suckers and minnows) a large portion of the resident population. The problems inherent in effectively sampling a river the size of the Columbia preclude definitive measurements. Other common species include sculpin, dace, and sticklebacks.

II.3-F.2 100-N Disposal Trench

Liquid waste from the N Reactor flows into a crib with the overflow going into a 1600-ft long dispersal ditch. Water seeping from the trench eventually reaches the Columbia River. No ecological studies have been performed on this disposal trench although periphytic algae and associated microscopic organisms are probably present. Some insect larvae may also be present. The trench was occasionally used by migrating waterfowl until it was partly screened and backfilled to prevent access.

II.3-F.3 200 Area Ponds and Ditches

A number of ponds and ditches in the vicinity of the 200-E and 200-W areas have received low-level aqueous waste. A total of 360 acres received waste, but only about 180 acres are in current use. Ecological studies have been performed on some of the sites. The ditches in general have sand substrates with a rapid rate of infiltration. Vegetation grows abundantly along the shores if not controlled.

Ecological studies have been in progress since June 1972 on Gable Mountain Pond and since July 1973 on U Pond. The shoreline vegetation around Gable Mountain Pond is predominately cattails and rushes; open sections are present near the inlet and at the northwest end where the overflow passes through a culvert in a dike. Figure II.3-F-4 represents the basic food-web present in both Gable Mountain Pond and U Pond. The biota is rich in terms of species diversity but additional work is needed to quantify the various populations. (Major taxa are shown in Table II.3-F-2.) Quantitative sampling is in progress on the 22 acre U Pond. The daily thermal regime of the pond is dependent primarily upon the incoming water and secondarily on atmospheric and solar heat. However, the range within which the pond fluctuates is influenced by seasonal changes in solar and atmospheric heat. Since primary productivity is closely related to seasonal changes in insolation and temperature, striking pulses occur during the warmer months when wind and cloud cover are minimal.

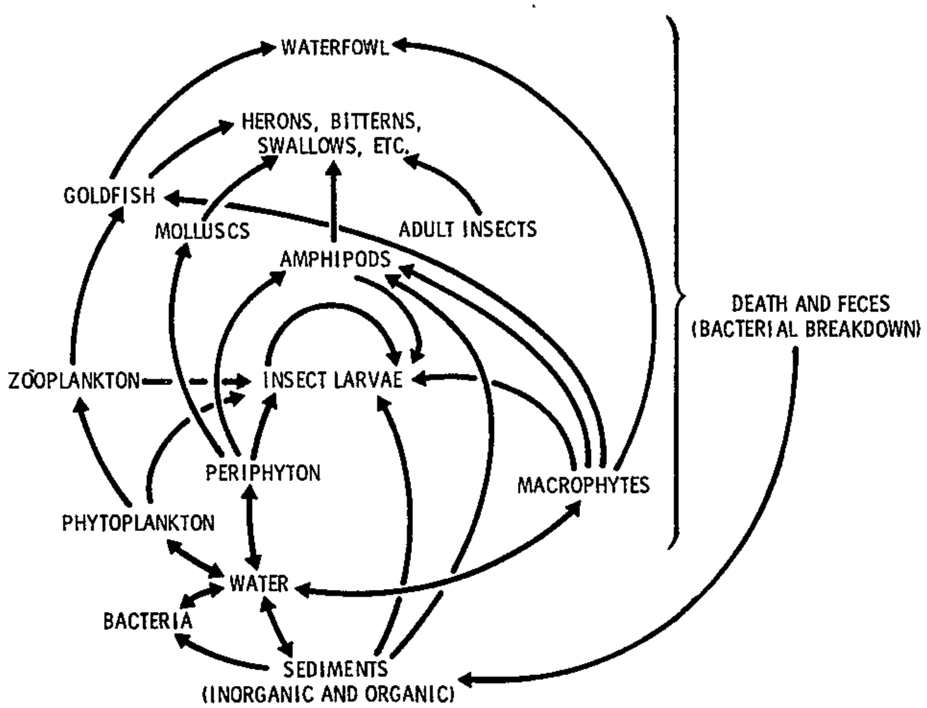

FIGURE II.3-F-4 FOOD WEB OF GABLE MOUNTAIN POND AND U POND

The pond supports a simple food-web based mainly on detritus and sedimented organic matter. Primary producers are mainly phytoplanktonic green algae (Chlorococcales) and several emergent vascular plants. Benthic detritivores and scavengers include chironomid larvae, oligochaetes, amphipods, and mayfly and beetle larvae. Goldfish, the only nektonic form, also scavenge the bottom. Dragonfly and damselfly larvae and backswimmers constitute the only known carnivores in the pond.

TABLE II.3-F-2

MAJOR TAXA IDENTIFIED IN GABLE MOUNTAIN POND AND U POND

Plants	Animals
Phylum Chlorophyta	Phylum Mollusca
Phylum Tracheophyta	Phylum Annelida
Family Typhacea	Phylum Arthropoda
Family Cyperacea	Class Crustacea
Family Najadaceae	Order Diplostraca
Family Haloragidaceae	Order Calanoida
	Order Cyclopoida
	Order Amphipoda
	Class Insecta
	Order Coleoptera
	Order Diptera
	Order Hemiptera
	Order Odonata
	Order Ephemeroptera
	Phylum Chordata
	Class Osteichthyes
	Order Holostei
	Family Cyprinidae

II.3-F.4 300 Area Waste Ponds

Two ponds, totalling about 12 acres, receive low-level liquid waste generated in the 300 Area laboratories and reactor fuel canning complex.[15] The South Pond is dry now but could receive water again since the North Pond is approaching capacity. Since the waste contains concentrations of copper and uranium, a thick layer of copper hydroxide is on the bottom.

No ecological studies have been conducted on these ponds. Vascular plants grow down to the water's edge, but the pond proper is unsuitable for aquatic life. Ducks are occasionally observed on the ponds and sanitary waste leaching trench alongside.

II.3-F.5 Rattlesnake Springs

Rattlesnake Springs, located in the Arid Lands Ecology (ALE) Reserve, is a permanent spring which begins from ground seepage and is subsequently fed by small ground springs along its course. It flows for approximately 2 miles at approximately 0.43 cfs and disappears into the ground. The stream bottom is composed of sand and gravel, while rubble occurs in some areas. The biotic communities in the stream are subjected to periodic flash floods in winter, depending upon weather conditions. Despite these floods, the stream supports a diverse flora and fauna. Table II.3-F-3 gives the mean concentrations of several chemical parameters; pH varies slightly around 8.0. No chemicals are present in detrimental concentrations to the biota.

II.3-F.5.1 Phytoplankton and Periphyton

Some 90 species of algae have been collected and identified at Rattlesnake Springs. Slightly over half of the species are diatoms. In summer, green algae are the second most numerous group and are the dominant group in terms of biomass. Table II.3-F-4 shows the breakdown by major taxonomic groups.

II.3-F.5.2 Macrophytes

Cattails and sedges occur along the stream, especially where it is not shaded, but the overwhelmingly dominant macrophyte is water cress, Rorippa nasturtium-aquatica. This plant seasonally occupies from 2 to 85% of the total stream area.[17]

TABLE II.3-F-3

CHEMICAL ANALYSIS,
RATTLESNAKE SPRINGS,
1962-1963

	ppm
Ca	30
Mg	11
Na	16
K	3
Zn	0.004
B	0.024
Fe	0.08
Si	24
SO_4	13 to 30
Cl	3
PO_4	0.3
NO_3	0.8
Total dissolved solids	220
MO alkalinity	132
Turbidity	1.2

TABLE II.3-F-4

MAJOR ALGAE TAXA
IN RATTLESNAKE SPRINGS

Taxon	No. of Species
Phylum Chlorophyta	
Sub-Division Chlorophyceae	22
Sub-Division Characeae	1
Phylum Euglenophyta	11
Phylum Chrysophyta	
Sub-Division Xanthophyceae	3
Sub-Division Chrysophyceae	46
Phylum Cyanophyta	
Sub-Division Myxophyceae	7

II.3-F.5.3 Invertebrates

Several groups of invertebrates occupy the stream, although the species diversity is highly dependent upon the size of the winter floods, if any, and the resulting physiognomy of the stream. No exhaustive taxonomic study has been made of the invertebrates. The major taxa are given in Table II.3-F-5.

TABLE II.3-F-5

MAJOR TAXA IDENTIFIED IN RATTLESNAKE SPRINGS

Plants	Animals
Phylum Chlorophyta	Phylum Mollusca
Sub-Division Chlorophyceae	Phylum Annelida
Sub-Division Characeae	Phylum Arthropoda
Phylum Euglenophyta	Class Crustacea
Phylum Chrysophyta	Order Ostracoda
Sub-Division Xanthophyceae	Order Diplostraca
Sub-Division Chrysophyceae	Order Calanoida
Phylum Cyanophyta	Order Cyclopoida
Sub-Division Myxophyceae	Order Amphipoda
Phylum Tracheophyta	Order Decopoda (not in Rattlesnake Springs)
Family Cruciferae	Class Insecta
Family Typhaceae	Order Coleoptera
Family Cyperaceae	Order Ephemeroptera
	Order Plecoptera
	Order Trichoptera
	Order Diptera
	Order Hemiptera
	Order Odonata

II.3-F.6 Other Springs on the ALE Site

Approximately 14 other permanent and intermittent springs occur on the ALE site. No ecological studies have been made of these springs but qualitative collections were made for certain organisms. Algae was collected at a few sites and the crayfish, Pacifasticus leniculatus, was collected for laboratory experiments.

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APPENDIX II.3-F, Part 2

Columbia River Biota

II.3-F, Part 2 Columbia River Biota[a]

Organism

Phylum Chlorophyta
- Ulothrix zonata
- Stigeoclonium lubricum
- Cladophera crispata
- C. glomerata
- Zoochlorella parasitica
- Chara Braunii Gmelin
- C. vulgaris
- Tetraspora sp.
- Oedogonium sp.
- Spirogyra sp.
- Plesdorina sp.
- Pediastrum sp.
- Staurastrum sp.
- Coelastrum sp.
- Ankistrodesmus sp.
- Pandorina sp.
- Scenedesmus sp.
- Rhizoclonium fontanum

Phylum Chrysophyta
- Hydrurus foetidus
- Botrydium granulatum
- Eunotia pectinalis
- Melosira granulata
- M. varians
- Cyclotella bodanica
- C. glomerata
- C. melosiroides
- Stephanodiscus astraea
- S. a. var. minuta
- S. niagarea
- Rhizosolenia eriensis
- Tabellaria fenestrata
- Diatoma vulgare
- Fragilaria crotonensis
- F. harrisonii
- F. construens
- F. virescens
- Asterionella formosa
- Synedra ulna
- S. u. var. danica
- S. acus
- S. rumpens
- S. pulchella
- S. parasitica
- Cocconeis placentula

Phylum Chrysophyta (contd)
- C. pediculus
- Frustulia rhomboides
- F. vulgaris
- Nedium productum
- Diploneis elliptica
- Navicula oblonga
- Cymbella prostrate
- C. turgida
- C. leptoceros
- C. naviculiformis
- C. cistula
- C. ventriocosa
- C. tumida
- Gomphonema parvulum
- G. olivaceum
- Epithemia turgida
- Rhopalodia gibba
- Nitzschia dissipata
- N. palea
- Ceratoneis sp.
- Cymatopleura solea
- C. elliptica
- Suriella linearis

Phylum Cyanophyta
- Aulosira implexa
- Oscillatoria anguina
- O. chalybea
- O. limosa
- O. proboscidea
- O. princeps
- O. spendida
- O. tenuis
- O. t. var. natans
- Phormidium autumnale
- P. favosum
- P. inundatum
- P. retzii
- P. subfuscum
- P. tenue
- P. uncinatum
- Lyngbya aeruginеocaerulea
- L. aestuarii
- L. Diguetii
- L. versicolor
- Symploca muscorum

Phylum Cyanophyta (contd)
- Anabaena oscillarioides
- Nostoc caeruleium
- N. ellipsosporum
- N. sphaericum
- Aphanizomenon flos-aquae
- Tolypothrix distorta
- T. lanata
- T. tenuis
- Plectonema nostocorum
- Amphithrix janthina
- Calothrix parietana
- Gloeotrichia echinulata
- G. natans
- Audouinella violacea

Phylum Pyrrhophyta
- Ceratium sp.

Phylum Tracheophyta
- Family Najadaceae
  - Potomogeton sp.
- Family Hydrocharitaceae
  - Anacharis sp.
  - Elodea sp.
- Family Lemnaceae
  - Lemna sp.
- Family Polygonaceae
  - Polygonum sp.
- Family Ceratophyllaceae
  - Ceratophyllum demersum
- Family Cyperaceae
- Family Juncaceae

Animals
- Phylum Protozoa
  - Acanthocystis sp.
  - Actinosphaerium sp.
  - Vorticella sp.
  - Epistylis sp.
- Phylum Porifera
  - Spongilla lacustris
- Phylum Coelenterata
  - Craspedacusta sowerbii
  - Hydra sp.

Phylum Platyhelminthes
- Class Turbellaria
  - Dugesia dorocephala
- Class Trematoda
  - Actinocleidus sp.
  - Urocleidus sp.
  - Dactylogyrus spp.
  - Gyrodactylus spp.
  - Phyllodistomum sp.
  - Lecithaster salmonis
  - Diplostomum sp.
  - Posthodiplostomum minimum
  - Brachyphallus crenatus
  - Neascus spp.
  - Allocreadium sp.
  - Crepidostomum farionis
  - Crepidostomum sp.
  - Octomacrum sp.
  - Cestrahelmins rivularus
  - Plagioporus spp.
- Class Cestoidea
  - Corallobothrium fimbriatum
  - Proteocephalus ambloplitis
  - P. ptychocheilus
  - P. salmonidicola
  - Phyllobothrium sp.
  - Caryophyllaeus sp.
  - Ligula intestinalis
  - Diphyllobothrium sp.
  - Bothriocephalus sp.
  - Schistocephalus solidius
  - Eubothrium salvelini

Phylum Aschelminthes
- Class Rotifera
  - Dapidia sp.
  - Kellicotia sp.
  - Syncheata sp.
  - Notholca sp.
  - Polyarthra sp.
  - Trichocerca sp.
  - Keratella sp.
- Class Nematoda
  - Rhabdochona sp.
  - Contracaecum sp.
  - Philonena onchorhynchi
  - Bulbodacnitus sp.
  - Metabronena sp.
  - Cystidicola sp.
  - Camallanus sp.

(a) Classification after - T. I. Storer, R. L. Usinger, R. C. Stebbins, J. W. Wybakken, General Zoology, Fifth edition, McGraw-Hill Book Co., New York, 1972.

Organism

Phylum Acanthocephala

- Neoechinorhynchus rutili
- N. cristatus
- Pomphorhynchus bulbocolli
- Bulbodactnitis sp.

Phylum Bryozoa

- Plumatella sp.
- Pectinatella sp.

Phylum Mollusca

Class Gastropoda

- Stagnicola nuttalliana
- Physa nuttallii
- Fluminicola nuttalliana
- Fisherola nuttallii
- Stagnicola apicina
- Radix japonica
- Gyraulis vermicularis
- Parapholyx effusa costata
- P. e. neritoides
- Lymnaea stagnalis
- Lymnaea sp.
- Planorbis sp.

Class Bivalvia

- Anodonta nuttalliana
- Corbicula fluminea
- Margaritifera margaritifera
- Pisidium columbianum
- Anodonta compressum
- Anodonta californiensis

Phylum Annelida

Class Oligochaeta

- Xironogiton instabilis
- Triannulata montana
- Chaetogaster sp.

Class Hirudinea

- Placobdella montifera
- Illinobdella moorei
- Erpobdella punctata
- Theromyzon rude
- Piscicola sp.
- Helobdella stagnalis

Phylum Arthropoda

Class Arachnida

- Hydracarina sp.
- Aranedia sp.

Class Crustacea

Order Anostraca

- Steptocephalus seali

Order Diplostraca

- Leptodora kindtii
- Diaphanosoma brachyurum
- Alona rectangula
- A. affinis
- A. quadrangularis
- A. costata
- Chydoris sphaericus
- Pleuroxus denticularis
- Sida crystallina
- Eurecercus lemallatus
- Camptocercus rectirostris
- Daphnia galeata mendotae
- Scapholebercis kingi
- Ceriodaphnia pulchella
- Bosmina sp.
- B. longirostis
- Illyocryptus sordidus
- I. spinifer
- Macrothrix laticornis
- Monospilus dispar
- Leydigia quadrangularis
- Pleuroxus trigonellus

Order Calanoida

- Canthocamptus sp.
- C. staphylinoides
- C. vernalis
- C. biscuspidatus thomasi
- Diaptomus sp.
- D. ashlandi
- Bryocamptus zschokkei

Order Cyclopoida

- Cyclops sp.

Order Amphipoda

- Gammarus sp.

Phylum Arthropoda (contd)

Order Decapoda

- Pacifasticus (lenius-culus) trowbridgii

Class Insecta

Order Coleoptera

- Gyrinus sp.

Order Ephemeroptera

- Paraleptophlebia bicornuta
- Baetis sp.
- Ephoron album
- Ephemerella yosemite
- E. sp.
- Hexagenia sp.
- Stenonema sp.

Order Plecoptera

- Arcynepteryx paralla
- Pteronarcys californica
- Isogenus sp.
- Perlodes americana

Order Trichoptera

- Glossosoma velona
- Hydropsyche cockerelli
- Hydropsyche sp.
- H. californica
- Leptocella sp.
- Limnophilus sp.
- Hydroptila argosa
- Brachycentrus occidentalis
- Rhacophila coloradensis
- Psychomyia flavida
- Cheumatopsyche enomis
- C. campyla
- Leucotrichia pictipes
- Arthripsodes annulicornis
- Mystacides alafimbriata
- Lepidostoma strophis

Order Lepidoptera

- Argyractis angulatalis

Order Diptera

- Tipulidae
- Chironomidae
- Simulium vittatum
- Simulium sp.

Order Hemiptera

- Notonecta sp.
- Gerris sp.
- Sigara sp.

Order Collembola

- Family Hypogasturidae

Phylum Tardigrada

- Macrobiotus sp.

Organism	
Phylum Chordata	
Class Cyclostomata	
Entosphenus tridentatus	Pacific Lamprey
Lampetra richardsoni	Western Brook Lamprey
Class Osteichthyes	
Acipenser transmontanus	White Sturgeon
Oncorhynchus tshawytscha	Chinook Salmon
O. nerka	Sockeye or Blueback Salmon
O. kisutch	Coho or Silver Salmon
Salmo gairdneri	Steelhead or Rainbow Trout
S. clarki	Cutthroat Trout
Salvelinus malma	Dolly Varden
Prosopium williamsoni	Mountain Whitefish
Alosa sapidissima	American Shad
Pantosteus platyrynchus	Mountain Sucker
Catostomus columbianus	Bridgelip Sucker
Catostomus macrocheilus	Largescale Sucker
Cyprinus carpio	Carp
Tinca tinca	Tench
Richardsonius balteatus	Redside Shiner
Ptychocheilus oregonensis	Northern Squawfish
Acrocheilus alutaceus	Chiselmouth
Mylocheilus caurinus	Peamouth
Rhinichthys atratulus	Blacknose Dace
R. cataractae	Longnose Dace
R. osculus	Speckled Dace
Ictalurus nebulosus	Brown Bullhead
I. melas	Black Bullhead
I. punctatus	Channel Catfish
I. furcatus	Blue Catfish
Gasterosteus aculeatus	Threespine Stickleback
Perca falvescens	Yellow Perch
Stizostedion vitreum	Walleye
Lepomis macrochirus	Bluegill
L. gibbosus	Pumpkinseed
Pomoxis annularis	White Crappie
P. nigromaculatus	Black Crappie
Micropterus salmonides	Largemouth Bass
M. dolomieui	Smallmouth Bass
Lota lota	Burbot
Cottus asper	Prickly Sculpin
C. beldingii	Piute Sculpin
C. perplexus	Reticulate
C. rhotheus	Torrent Sculpin

APPENDIX II.3-G

TERRESTRIAL ECOLOGY

APPENDIX II.3-G-1

TERRESTRIAL ECOLOGY

II.3-G, Part 1 Terrestrial Ecology [X.24]

II.3-G.1 Climatic Influences

The Hanford region is frequently referred to as a "steppe" because of its resemblance to the steppeland of central Asia. The region is called[1] a shrub-steppe to differentiate the area from true steppes with more grasses and fewer shrubs. However, other points of contrast between Hanford and steppes in general deserve comment because they are fundamental to the structure and function of the ecosystems in the region; these include the causes of aridity and the relationships between precipitation and temperature.

True steppes have some common characteristics: 1) little precipitation, with the maximum occurring in summer and 2) wide daily and annual temperature ranges. The causes of aridity usually stem from a lack of storm tracks, with a substantial fraction of the annual precipitation coming from summer thunderstorms. However, Hanford's aridity arises from its geographical location in the rain shadow of the Cascade Mountains. Lying in the path of frequent winter storm tracks, the Hanford region is visited by many winter storms that bring clouds but little water. Summer thunderstorms average fewer than 10 annually, compared with 30 or more observed in classic steppelands.[2] These differences have led climatologists to classify the Hanford region variously as a cool desert, a winter-wet cool steppe, or a mid-latitude desert.[1,2]

The winter maximum of precipitation is graphically shown in Figure II.3-G-1 in terms of the deviation of precipitation from the average monthly amount if the total precipitation were evenly distributed throughout the year. Temperature deviations are likewise shown in terms of monthly deviations from the annual mean temperature. The regular, nearly sinusoidal pattern of the temperature deviations contrasts with the much less regular precipitation pattern. Precipitation is relatively high during the winter months (2 to 3 cm per month on the average). Although June exhibits a secondary maximum, the June precipitation is too little and too late to be of substantial importance to the vegetation because the rains usually wet the soil only to a depth of 20 cm or so, well within the reach of evaporation by the high insolation intensities and warm soil temperatures of that season.[3] Consequently, the only precipitation of importance to vegetation is that which is stored as soil water during the cool season.[4]

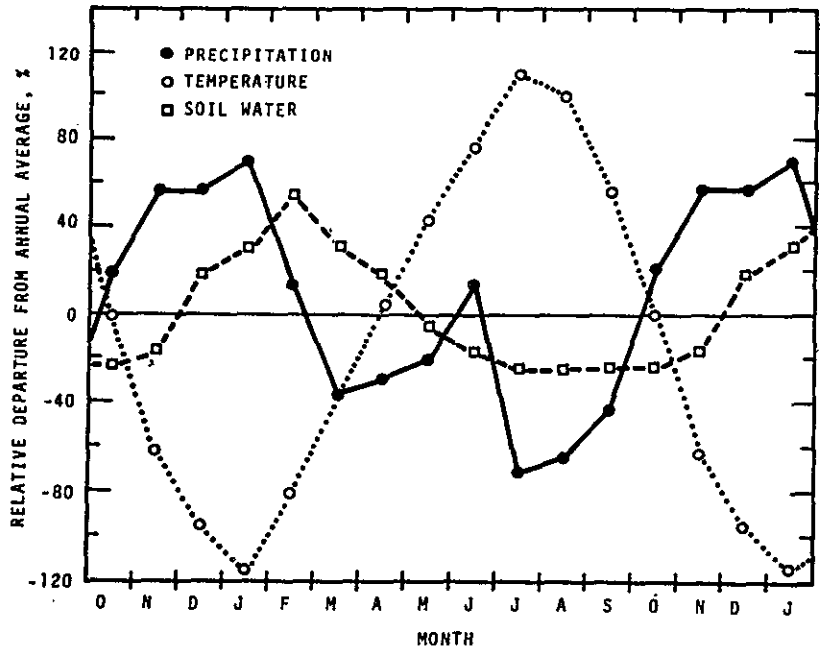

FIGURE II.3-G-1 RELATIVE DEPARTURE OF TEMPERATURE, PRECIPITATION AND SOIL WATER FROM THEIR RESPECTIVE ANNUAL AVERAGES

Typically, about half of the winter precipitation occurs as snow, but snow cover is usually short-lived and offers an undependable shield against cold and dessicating winter wind.[5] Snow is not always a reservoir of water for later use; falling as it does in an arid zone, it may blanket bare, frozen soil. Subsequent warm winds (chinooks) will melt the snow but not the soil, causing rapid runoff of the entire snow inventory.[6] This tendency is most pronounced at the higher elevations where enough relief initiates runoff.

Rainfall in the Hanford region is clearly dependent upon elevation,[7] increasing significantly in the high elevations of the Rattlesnake Hills (Figure II.3-G-2). The rate of increase with elevation is much more rapid at lower elevations than at the higher elevations, and wind interacts with precipitation patterns to produce substantial accumulations (snow drifts) on lee slopes. These alterations in precipitation provide the impetus for relatively far-reaching changes in plant communities, especially in terms of species present.

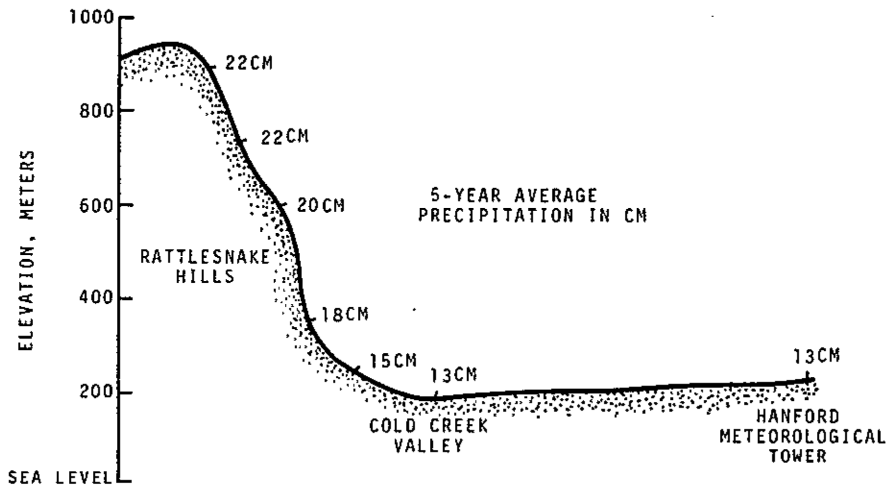

FIGURE II.3-G-2 AVERAGE "BIOYEAR" (OCTOBER THROUGH MARCH) PRECIPITATION AS A FUNCTION OF ELEVATION ON THE ARID LANDS ECOLOGY RESERVE

The middle elevations of the Rattlesnake Hills are at the top of a persistently occurring nighttime inversion of temperature over the Hanford Reservation, i.e., air temperatures at night are 2 to 10°C warmer at about 400 m elevation than at the valley floor.[5] Consequently, the freeze-free season at midelevations is about 4 to 6 weeks longer than at either lower or higher elevations and therefore the soils may not freeze so deeply. In early spring, when soil water is plentiful, this temperature difference can induce noticeable advancement of the flowering time of plant species growing at midelevations.

Wind speeds in the Hanford region average moderate because very strong winds are separated by lengthy periods of light winds. Winds are of substantial ecological importance because they erode mobile surfaces and increase evaporation at higher elevations. Erodible soils exist on the Reservation--indeed, much of its surface is mantled by previous wind-laid deposits. Sands are the only size range physically able to form dunes,[8] but silts can be made airborne when disturbed by saltating ("jumping") sand grains. The shear stress of the wind at the earth's surface determines whether sufficient force exists to move sand grains. Where vegetation exists, the shear stress is reduced sharply and erosion is minimized. However, if the vegetation is removed, by fire, construction, plowing, or other means, strong winds will erode sandy soils. Most of the soils in the Hanford region have a substantial sand fraction and are therefore more or less erodible by winds, especially at the lower elevations where vegetation is sparser and sandier soils exist.[9]

The Rattlesnake Hills are much higher than any surrounding terrain for many kilometers and are therefore subject to nearly free-stream wind speeds. During the windy season, winter and spring, winds are relatively constant and strong on the ridgetops, leading to a vegetation type consisting largely of cushion-form plants and grasses. However, even at more moderate elevations and exposures, the tendency for higher wind speeds at higher elevations increases evaporation of water from plant and, especially, soil surfaces. The increased water loss may amount to a centimeter or two during the spring growing season.[10] Because only 3 to 5 more centimeters of precipitation may be at the higher elevations (Figure II.3-G-2), wind reduces the biological importance of the extra precipitation by a substantial fraction. "Books about nature seldom mention wind; they are written behind stoves."[11]

II.3-G-2 Soil

Soils play an indispensable role in the ecological distribution of plant and animal communities on the Hanford Reservation. Soils provide water storage, essential nutrients, and physical support for plants, as well as a refuge for many kinds of animals from the rigors of wind and extreme temperature fluctuations in both summer and winter.

Soils of the Hanford Reservation differ markedly in their physical and chemical properties and productivity, the results of the unique set of soil-forming factors which brought these soils to their present state. These factors are: 1) the parent material from which the soils were formed, 2) the climate under which the soils were formed, 3) the relief, including both slope and exposure, of each site, 4) the vegetation growing on each site, and 5) the period in which factors 2, 3, and 4 above have operated.

Soils of the Hanford Reservation formed in five kinds of parent material, including recent alluvium, old alluvium (glacial outwash), windblown sand, lacustrine (lake-laid) deposits, and loess (wind-laid deposits). Basalt bedrock underlies all of these deposits. The minerology of the parent material is varied, resulting in part from weathering of local basalts and in part from weathering of igneous and metamorphic rocks to the north and east of the Hanford Reservation.

Relief affects soil formation through its influence upon precipitation, drainage, runoff, and normal and accelerated erosion. Vegetation affects soil formation by producing organic matter, which in turn influences water holding capacity, infiltration, fertility, and structure.

In the Hanford region, average annual precipitation varies from 13 to 26 cm, so the organic matter in the soil also varies widely, as shown by the color of the soil. Where annual precipitation is 22 cm or less, the organic content of the surface soil is generally less than 1% and the soil is dark grayish brown when moist.[12] In contrast, where annual precipitation amounts to 22 to 30 cm, the organic content of the surface soil is 1 to 2% and the surface soil is generally very dark grayish brown when moist.

II.3-G.2.1 Description and Classification of Hanford Reservation Soils

The soils of the Hanford Reservation have been mapped, described, and classified.[9] Physical and chemical characteristics of major soil series of the Hanford Reservation are also available.[13]

Soils which are alike in all characteristics except texture are grouped into soil series. If the texture class is added to the series, the soil unit is classed a soil type. The soil type was the unit mapped in a recent survey;[9] however, small areas of other soil types were included in the delineation. For these reasons the soil type, indicated on the map (Figure II.3-G-3) and described subsequently, represents the predominant type of soil in the delineation: in uniform areas, the type indicated is representative of the entire area enclosed; in the others, inclusions of other soils occur. In addition, because soil boundaries seldom change abruptly, transitional areas are included.

II.3-G.2.1.1 Soil Descriptions

Ritzville Silt Loam (Ri)

This mapping unit consists chiefly of dark colored silt loam soils which developed midway up the slopes of Rattlesnake Hills. These soils developed under bunch grass from silty wind-laid deposits mixed with small amounts of volcanic ash. The surface, an 8 inch layer, is usually very dark grayish brown (10YR^3/2)[(a)] grading with depth to a dark grayish brown (10YR^4/2) silt loam subsoil. Small areas of very fine sandy loam are included in addition to Warden, Lickskillet, and Scooteney soils.

Ritzville soils are characteristically greater than 60 inches deep but in places bedrock may occur between 60 and 30 inches deep.

(a) Munsell color designation indicating hue, chroma, and value.

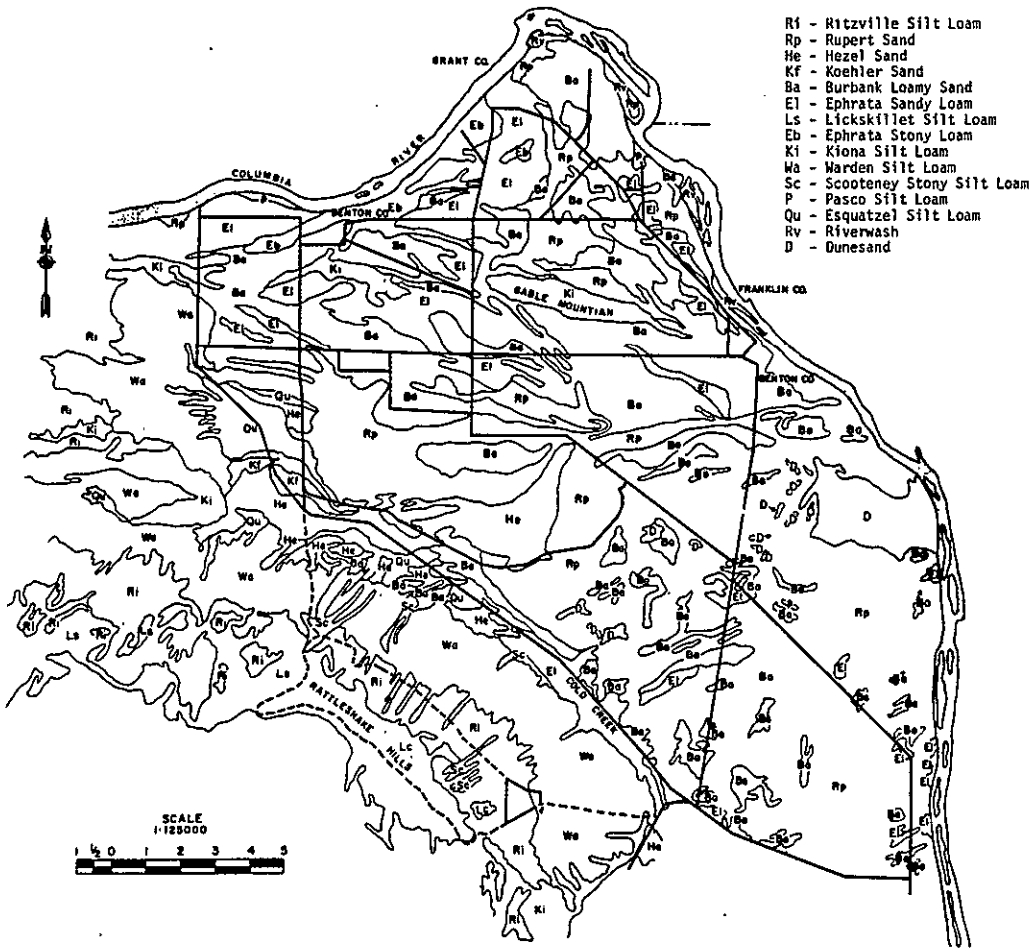

FIGURE II.3-G-3 SOIL MAP OF THE HANFORD RESERVATION IN BENTON COUNTY WASHINGTON[9]

Rupert Sand (Rp)

This mapping unit represents one of the most extensive soils on the Hanford Reservation. The surface is a brown to grayish brown (10YR^5/2) coarse sand which grades to a dark grayish brown (10YR^5/2) sand at about 36 inches. Rupert soils developed under grass, sagebrush, and hopsage in coarse sandy alluvial deposits which were mantled by wind-blown sand. Relief characteristically consists of hummocky terraces and dune-like ridges. This soil may be correlated to Quincy sand, which was not separated here.

Active sand dunes are present. Although some dune areas are separated, many small dunes, blowouts, and associated small areas of Ephrata and Burbank soils are included.

Hezel Sand (He)

Hezel soils, similar to Rupert sands, are a laminated grayish brown (10YR^5/2) strongly calcareous silt loam subsoil usually encountered within 40 inches of the surface. The surface soil is very dark brown (10YR^3/3) and was formed in wind-blown sands which mantled lake-laid sediments. Areas of Rupert, Burbank, and blow-outs are included.

Koehler Sand (Kf)

Koehler soils are similar to the other sandy soils found on the Hanford Reservation. They developed in a wind-blown sand mantle. This soil differs from the other sands in that the sand mantles a lime-silica cemented layer "hardpan." The very dark grayish-brown (10YR^3/2) color of the surface layer is somewhat darker than Rupert. The calcareous subsoil is usually dark grayish brown (10YR^4/2) at about 18 inches. Inclusions are of the Rupert and Burbank series.

Burbank Loamy Sand (Ba)

This is a dark-colored coarse-textured soil which is underlain by gravel. The surface is very dark grayish brown (10YR^3/2), while the subsoil is dark grayish brown (10YR^4/2). The surface soil is usually about 16 inches thick but can be 30 inches thick. The gravel content of the subsoil may range from 20 to 80 vol%. Areas of Ephrata and Rupert are included.

Kiona Silt Loam (Ki)

This soil occupies steep slopes and ridges. The surface soil is very dark grayish brown (10YR^3/2) and about 4 inches thick. The dark brown (10YR^4/3) subsoil contains basalt fragments 12 inches and larger in diameter. Many basalt fragments also are found in the surface layer and basalt rock outcrops are present. Normally this shallow stony soil occurs in association with Ritzville and Warden soils. Many areas of stony silt loam and very shallow Lithosols are included.

Warden Silt Loam (Wa)

This is a dark grayish brown soil (10YR^4/2) whose surface layer is usually 9 inches thick. The silt loam subsoil becomes strongly calcareous and lighter colored grayish brown (10YR^5/2) at about 20 inches. Granitic boulders are found in many areas. Usually this soil is greater than 60 inches deep. Associated soils and inclusions are of the Ritzville, Kiona, Esquatzel and Scooteney series. At higher elevations (1200 feet), Warden soils grade to Ritzville silt loam.

Ephrata Sandy Loam (El)

This is a dark colored medium-textured soil underlain by gravelly material which may continue for many feet. The surface is very dark grayish brown (10YR^3/2), while the subsoil is dark grayish brown (10YR^4/2). Since this soil is associated with the Burbank soil, many small areas were included in delineations of this soil type. The topography is generally level.

Ephrata Stony Loam (Eb)

This soil is similar to Ephrata sand loam but differs in that many large hummocky ridges are present which are made up of debris released from the melting ice of glaciers. Areas between hummocks contain many boulders several feet in diameter. Ephrata sandy loam and Burbank loamy sand are associated and included.

Scooteney Stony Silt Loam (Sc)

This soil developed along the north slope of the Rattlesnake Hills, usually confined to floors of narrow draws or small fan-shape areas where draws open onto plains. The soils are often severely eroded with numerous basaltic boulders and fragments being exposed. The surface soil is usually dark grayish brown (10YR^4/2) grading to grayish brown in the subsoil. Many small areas of Warden and Ritzville are included.

Pasco Silt Loam (P)

This is a poorly drained very dark grayish brown (10YR^3/2) soil formed in recent alluvial material. The subsoil is variable, consisting of stratified layers. Only small areas of this soil are found on the Hanford Reservation, located in low areas adjacent to the Columbia River. Areas of riverwash may be included.

Esquatzel Silt Loam (Qu)

This is a deep dark brown (10YR^3/3) soil formed in recent alluvium derived from loess and lake sediments. The subsoil grades to dark grayish brown (10YR^4/2) in many areas but color and texture of the subsoil is variable due to the stratified nature of the alluvial deposits. Esquatzel soils are associated with Ritzville and Warden and often seem to have developed from sediments eroded from these two series.

Riverwash (Rv)

These are wet, periodically flooded areas of sand gravel and boulder deposits which make up overflowed islands in the Columbia River and adjacent to the river.

Dune Sand (D)

This unit represents a miscellaneous land type which consists of hills or ridges of sand-sized particles drifted and piled up by wind and are either actively shifting or so recently fixed or stabilized that no soil horizons have developed. In places, recently blown-out land and areas of Rupert sand are included. Many small active dunes and accompanying blown-out areas are included with other soils, mostly Rupert, Hezel and less frequently Burbank.

Lickskillet Silt Loam (Ls)

This soil occupies the ridge tops of Rattlesnake Hills and slopes above the 2500-ft elevation. The soil is similar to the Kiona series except that the surface soils are a very dark brown (10YR^2/2 to ^{3}/2). Lickskillet soils are shallow over basalt bedrock. Numerous basalt fragments are present throughout the profile. Many areas of very stony silt loam and Ritzville soils are included.

II.3-G.2.1.2 Soil Classification

The correlation from the earlier Hanford soil survey[9] into the present system appears in Table II.3-G-1. In addition to the correlations shown, many small areas of soil were included with surrounding or adjacent large bodies of soils.

TABLE II.3-G-1

CLASSIFICATION OF SOIL SERIES OF BENTON COUNTY AREA[12]

	Current Classification			1938 Classification	
Series	Family	Subgroup	Order	Great Soil Group	Order
Ritzville silt loam	Coarse-silty, mixed, mesic	Calciorthidic Haploxerolls	Mollisol	Brown soils	Zonal
Rupert sand	--	--	--	--	--
Koehler sand	Sandy, mixed, mesic	Xerollic Durorthids	Aridisol	Regosols	Azonal
Hezel sand	Coarse-loamy, mixed, nonacid, mesic	Typic Torriorthents	Entisol	Regosois	Azonal
Burbank loamy sand	Mixed, mesic	Typic Torripsamments	Entisol	Regosols	Azonal
Ephrata sandy loam	--	--	--	--	--
Lickskillet silt loam	Loamy-skeletal, mixed, mesic	Aridic Lithic Haploxerolis	Mollison	Chestnut soils	Zonal
Ephrata stony loam	--	--	--	--	--
Kiona silt loam	Loamy-skeletal, mixed, mesic	Xerollic Camborthids	Aridisol	Brown soils	Zonal
Warden silt loam	Coarse-silty, mixed, mesic	Xerollic Camborthids	Aridisol	Sierozems	Zonal
Scooteney stony silty loam	Coarse-loamy, mixed, mesic	Xerollic Camborthids	Aridisol	Sierozems	Zonal
Pasco silt loam	Coarse-silty, mixed, mesic	Cumulic Haploxerolls	Mollisol	Alluvial soils	Azonal
Esquatzel silt loam	Coarse-silty, mixed, mesic	Torrifluventic Haploxerolls	Mollisol	Alluvial soils	Azonal
Riverwash	--	--	--	--	--
Dunesand	--	--	--	--	--

Table II.3-G-2 lists the approximate higher category and engineering classification of soil types on the Hanford Reservation. The Unified and A.A.S.H.O. engineering classification systems are based on characteristics which influence engineering behavior of soil, mostly on grain size, plasticity, and load limits. Brief descriptions of the engineering categories are given in the following outline:

A.A.S.H.O. (American Association of State Highway Officials)

- Group A-1. Typically this is a well-graded mixture of stone fragments or gravel, coarse sand, fine sand, and a nonplastic or pebble plastic soil binder. This group also includes stone fragments, gravel, coarse sand, etc., without soil binder.

- Group A-2. This group comprises a wide variety of granular material which is at the border line between groups A-1 and A-3. It includes any material of which not more than 35% will pass through a No. 2 sieve and cannot be classified as A-1 or A-3 because of having fines, plasticity, or both in excess or limitation for these groups.

TABLE II.3-G-2

APPROXIMATE CLASSIFICATION OF HANFORD SOILS IN ENGINEERING CATEGORIES[9]

Soil Type	Classification Unified	Classification A, A, S, H, O,
Ritzville silt loam	ML	A-4
Rupert sand	Surface SM Subsoil SP to SM	A-4
Hezel sand	Surface SM Subsoil ML	A-2 A-4
Koehler sand	SM	A-2
Burbank loamy sand	Surface SM Subsoil GM to GP	A-2 A-2 to A-4
Ephrata sandy loam	Surface SM to ML Subsoil ML	A-2 to A-4 A-4 to A-1
Lickskillet silt loam	ML to GM	A-4 to A-1
Kiona silt loam	GM	A-1
Warden silt loam	SM to ML	A-2 to A-4
Scooteney stony silt	SM to ML	A-2 to A-4
Ephrata stony loam	Surface SM-ML Subsoil ML	A-2 to A-4 A-4 to A-1
Pasco silt loam	SM to ML	A-4
Esquatzel silt loam	SM to ML	A-4
Riverwash	GP	A-1
Dune sand	SP to SW	A-3

- Group A-3. This soil group is a fine beach sand or fine desert blow sand without silty or clayey fines or with a very small amount of nonplastic silt.
- Group A-4. Typically Group A-4 is a nonplastic or moderately plastic silty soil with more than 36% of the material passing through a No. 200 sieve. The usual type of significant constituent material is silt.

Unified System

- Group ML. Group ML is predominately silty material and micaceous or diatomaceous soils. The soils usually are sandy silts, clayey silts, or inorganic silts with relatively low plasticity. Also included are loessial soils and rock flours.
- Group GM to SM. These groups include gravels or sands which contain more than 12% fines that have little or no plasticity. Both well graded and poorly graded materials are included. Some dry strength may be provided by cementation of calcareous materials or iron oxides.
- Groups GP to SP. Poorly graded sands and gravels containing less than 5% of nonplastic fines constitute these groups. They may consist of uniform gravels, uniform sands, or nonuniform mixtures of very coarse material and very fine sand with intermediate sizes lacking.
- Groups GW to SW. These groups comprise well-graded sandy and gravelly soils which contain less than 5% of nonplastic fines passing through the No. 200 sieve. Fines which are present must not noticeably interfere with the free draining characteristics of this group.

Table II.3-G-3 gives the approximate land use capability classification of Hanford Reservation soils. This is a practical grouping of soils based on 1) limitations of soils for possible cropland and pasture use and 2) on the risk of damage when they are used. The classification shown is the broadest grouping; subclasses and units are lower groups within this system but are

TABLE II.3-G-3

SOIL CAPABILITY CLASSIFICATION

Soil Type	Dryland	Irrigated
Ritzville silt loam	III-VII	I-IV
Rupert sand	VII	IV
Koehler sand	VII	IV
Hezel sand	VII	IV
Burbank loamy sand	VII	IV
Ephrata sandy loam	VI	II-IV
Lickskillet silt loam	VI & VII	---
Ephrata stony loam	VI	---
Kiona silt loam	VI	---
Warden silt loam	IV	I-IV
Scooteney stony silty loam	VI	---
Pasco silt loam	IV	III
Esquatzel silt loam	III	I
Riverwash	VIII	---
Dunesand	VIII	---

not included. Dryland and irrigated capability units are used because of the increased potential of the soil when irrigated. The capability units are the same when the same hazards exist in both cases.

The following are descriptions of capability classes:

- Class I. These soils have few limitations and have wide latitude for use. Soils classes in this group are deep, productive, easily worked, and nearly level. No wind or water erosion hazard exists.
- Class II. Soils in this group have moderate limitations in use and are subject to moderate risk of damage. These are good soils; however, some special conservation attention is necessary due to slopes, erosion, depth, drainage, or overflows.
- Class III. These soils are subject to severe limitations in use for cropland because of moderately steep slopes, severe erosion hazards (wind or water), inherently low fertility. Intensive conservation practices are needed to farm this class of soil safely.
- Class IV. This class consists of soils that have very severe permanent limitations or hazards for cropland use. These limitations may be caused by steep slopes, wind, or water erosion hazards, or a dry, arid climate.
- Class V. Soils in this class should be kept in permanent vegetation used for pasture or forestry. Cultivation is not feasible because of wetness or stoniness.
- Class VI. Class VI soils should be used for grazing and forestry and may have moderate hazards when in this use. These soils are steep, or shallow over bedrock and stony. Erosion susceptibility is high.
- Class VII. These soils can be used for grazing or forestry; however, the steep, eroded rough stony or very dry sandy condition causes severe permanent limitations to use.
- Class VIII. These soils are suitable only for wildlife, recreation, or watershed uses.

II.3-G.3 Vegetation

II.3-G.3.1 Primary Plant Descriptions

The vegetation mosaic of the Hanford Reservation consists of eight major kinds of shrub-steepe communities identified by the most conspicuous or most abundant plant species:

- Sagebrush/bluebunch wheatgrass
- Sagebrush/cheatgrass or Sagebrush/Sandberg's bluegrass
- Sagebrush-bitterbrush/cheatgrass
- Greasewood/cheatgrass-saltgrass
- Winterfat/Sandberg's bluegrass
- Thyme buckwheat/Sandberg's bluegrass
- Cheatgrass-tumble mustard
- Willow

Onsite locations where these several communities predominate are shown in Figure II.3-G-4. (Figure II.3-G-15 shows place and direction of view of subsequent plant community figures.)

On the Hanford Reservation, the sagebrush/bluebunch wheatgrass (Figure II.3-G-5) vegetation-type occupies extensive acreage in the Rattlesnake Hills, mostly confined to the ALE Reserve (Figure II.3-G-6). In the absence of fire, sagebrush is the most conspicuous plant, but perennial grasses (bluebunch wheatgrass and Sandberg's bluegrass) contribute most of the plant biomass. In the event of fire, sagebrush is killed but the perennial grasses are not (Figure II.3-G-7). Over time, sagebrush is expected to return to burned areas, but this is a slow process that probably does not occur during the average human lifetime. Bluebunch wheatgrass is the most important livestock forage plant on the Hanford Reservation.

The most broadly distributed vegetation-type on the Hanford Reservation is the sagebrush/cheatgrass (Figure II.3-G-8 and Figure II.3-G-9) or sagebrush/Sandberg's bluegrass association. This vegetation-type occurs as a broad zone between the sagebrush/bluebunch wheatgrass type and the sagebrush-bitterbrush/cheatgrass type. The sagebrush/cheatgrass type differs from the sagebrush/bluebunch wheatgrass principally in that wheatgrass is absent, but another important difference is that sagebrush plants also tend to be larger in size and provide more ground cover. Spiny hopsage and rabbitbrush may be intermingled with sagebrush shrubs. Fire can burn through this kind of vegetation, killing sagebrush, but hopsage and rabbitbrush survive burning, sending out new growth during the growing season following the fire. Recovery of this vegetation following fire is not as readily apparent as in the sagebrush/bluebunch wheatgrass bluegrass vegetation because large perennial grasses are scarce. The general paucity of herbaceous cover also tends to favor invasion by tumbleweed, with or without fire. The sagebrush/cheatgrass and sagebrush/Sandberg's bluegrass communities provide very limited forage for livestock or wildlife.

The sagebrush-bitterbrush/cheatgrass (Figure II.3-G-10) vegetation-type occupies the low elevations in the southeastern sector of the Hanford Reservation. This vegetation-type differs from the sagebrush/cheatgrass type by having bitterbrush intermingled among the sagebrush shrubs. Also, snow eriogonum, a small shrub, is often locally abundant. The sagebrush-bitterbrush/cheatgrass vegetation-type occupies the sandiest soil short of dunes. Fire is especially destructive in this vegetation-type because sagebrush and bitterbrush are both killed by burning and the sandy soil is especially susceptible to wind erosion when protective vegetation cover is destroyed. The colonization of sandy soils in an arid environment is a slow process, especially if large areas are burned and seed sources severely reduced. The most efficient early invader of burned areas in the sagebrush-bitterbrush/cheatgrass vegetation-type is tumbleweed. Bitterbrush is an important forage plant for mule deer, especially in fall and winter.

The greasewood/cheatgrass-saltgrass (Figure II.3-G-11) vegetation-type is restricted to a small area of about 100 acres in the vicinity of Rattlesnake Springs.[14] This vegetation-type is important because the geographic distribution of greasewood is determined by the presence of a relatively shallow water table. Greasewood has an extensive root system and can extract water from a depth of 12 meters at Rattlesnake Springs, remaining succulent throughout the summer when other upland shrubs are dried from summer drought. Greasewood is known to be a salt accumulator.[15] The greasewood/cheatgrass-saltgrass vegetation-type provides little forage.

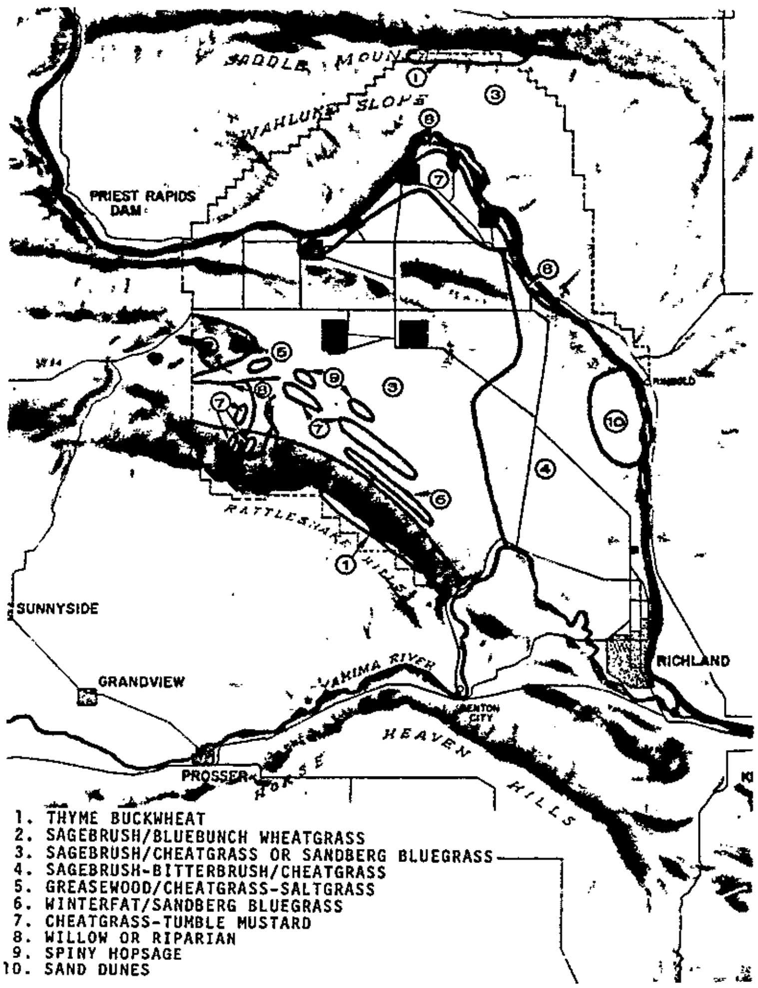

FIGURE II.3-G-4 DISTRIBUTION OF VEGETATION TYPES ON THE HANFORD RESERVATION

The winterfat/Sandberg's bluegrass (Figure II.3-G-12) vegetation-type occupies several thousand acres along the gentle lower slopes of the Rattlesnake Hills. For the most part, winterfat is restricted in geographic distribution to the ALE Reserve. In the years prior to government acquisition of the Hanford Reservation lands, the winterfat areas were used as winter pastures for sheep, because winterfat is a nutritious and palatable forage plant for livestock.

The thyme buckwheat/Sandberg's bluegrass (Figure II.3-G-13) vegetation-type occupies thin, stony soils along ridge crests in the Rattlesnake Hills and Gable Mountain areas. These communities have no potential for agricultural use other than to provide limited forage for livestock and wildlife, but they possess great aesthetic value because of the presence of many species with showy flowers. These species are of substantial botanical interest because of their floristic composition and morphological, physiological and genetic adaptations to living in a stressed environment.

FIGURE II.3-G-5 SAGEBRUSH/BLUEBUNCH WHEATGRASS COMMUNITY. (The shrub is big sagebrush and the large bunchgrass is bluebunch wheatgrass.)

The cheatgrass/tumble mustard (Figure II.3-G-14) vegetation-type occupies abandoned agricultural fields, especially in the 100 Areas and on the ALE Reserve. This vegetation-type is comprised mostly of alien annual plants, i.e., cheatgrass and annual mustards. Over the past 30 years invasion by native perennial grasses and shrubs and colonization by tumbleweed have been resisted. The ecological behavior of cheatgrass/tumble mustard communities has been studied on the ALE Reserve.[3,4,16,17,18,19] Cheatgrass/tumble mustard communities in the absence of livestock grazing are effective in binding soil against wind and water erosion.

Willow vegetation (Figure II.3-G-16) occurs along the banks of the Columbia River, waste ponds in the 200 Areas, abandoned agricultural irrigation ditches in the 100 Areas and along permanent spring courses in the Rattlesnake Hills. Although the amount of acreage occupied by willow communities is small, their value to wildlife is large. Willows and associated deciduous trees, shrubs and herbaceous plants provide food and nest sites for game and song birds, summer forage, and cover for mule deer.

FIGURE II.3-G-6 ARID LANDS ECOLOGY RESERVE

Miscellaneous vegetation-types occur throughout the Hanford Reservation. Of particular importance are deciduous trees around waste ponds,[20] abandoned homesteads, and abandoned military installations that provide nesting and resting sites for raptorial birds of prey. (A current floristic list for the Hanford Reservation is provided in Part 2 of this Appendix.)

Ecological aspects of waste management are important for some of the vegetation types, particularly the sagebrush/cheatgrass type (around the 200 and 300 Areas) and some cheatgrass/tumble mustard type (around the 100 Areas).

II.3-G.3.2 Pattern of Secondary Plant Succession

The historical pattern of plant succession in the steppe region of Washington has been altered during the past century by the introduction of annual weeds from the steppes of Eurasia. One of the most aggressive of these plants is cheatgrass. Cheatgrass is well adapted to the fall-winter precipitation regime of the area because its seeds are highly viable and seedling growth is more competitive than that of native perennial grasses. Abandoned agricultural fields 30 years old continue to be dominated by cheatgrass; apparently the competition for soil, water, and available essential mineral nutrients is sufficient to exclude other kinds of plants for long periods of time.

Tumbleweed, another exotic plant, has an effective method of seed dispersal. Tumbleweed is not as competitive as cheatgrass in most habitats, but it is the most successful colonizer of habitats where cheatgrass is suppressed by mechanical means or herbicides, or in soils with heterogeneous texture. In the absence of physical disturbance, cheatgrass and tumbleweed are not effective in invading pristine steepe communities. Nevertheless, cheatgrass and tumbleweed will become more important on the Hanford Reservation as soil is disturbed by construction and waste burial sites.

FIGURE II.3-G-7 SAGEBRUSH/BLUEBUNCH WHEATGRASS COMMUNITY. (Burned in 1957. The shrub in the foreground is rabbitbrush, a shrub that can sprout following fire damage; sagebrush is usually killed by fire.)

II.3-G-4 Mammals

The mule deer is the only big game mammal normally found on the Hanford Reservation, although a white-tail deer has been recorded.[21] A single elk resided on the Reservation for a few months in 1971-72, probably a migrant from the Blue Mountains 70 miles to the east. Most of the mule deer on the Hanford Reservation occur along the Columbia River, with smaller concentrations near Gable Mountain and the 200 Area, at Rattlesnake Springs, and on the Snively Ranch area in the Rattlesnake Hills. Over the past years, 180 fawns (from near the Columbia River only) have been tagged and released. Tagged animals have been taken during the legal hunting season as far away as Prosser, Washington, along the Yakima River; Mattawa, Washington, in the Saddle Mountains; and near the Walla Walla River.[22]

The cottontail rabbit is the only small game mammal, with small populations scattered throughout the Reservation area. The raccoon is probably the most abundant furbearing mammal on the Hanford Reservation, mostly confined to shoreline areas of the Columbia River and waste ponds in the 200 Areas. Beaver and muskrats occur in backwater areas of the Columbia River, while

FIGURE II.3-G-8 SAGEBRUSH/CHEATGRASS COMMUNITY. (The shrub is big sagebrush, the dense grass understory is mostly cheatgrass, an alien weed introduced to the Pacific Northwest with the advent of livestock grazing and agriculture. These growths are prevalent on the low-elevations of the Hanford Reservation.)

muskrats are found in wasteponds and ditches in the 200 Areas. Mink occur along the Columbia River and weasels are scattered throughout the Hanford area. The coyote is abundant on the Hanford Reservation as compared to adjacent land areas, although no accurate estimate of population density has been made. The bobcat and badger are present on the Reservation, but in low numbers.

The jackrabbit is widely distributed on the Hanford Reservation; however, it is less abundant in the sagebrush/bluebunch wheatgrass vegetation than in the sagebrush/cheatgrass and sagebrush-bitterbrush/cheatgrass vegetation-types. The jackrabbit is an important food item for coyotes and raptors.

Porcupines are widely distributed over the Reservation area but are especially abundant along the Columbia River. Porcupines occur in the 200 Areas and in the canyons and valleys of the Rattlesnake Hills.

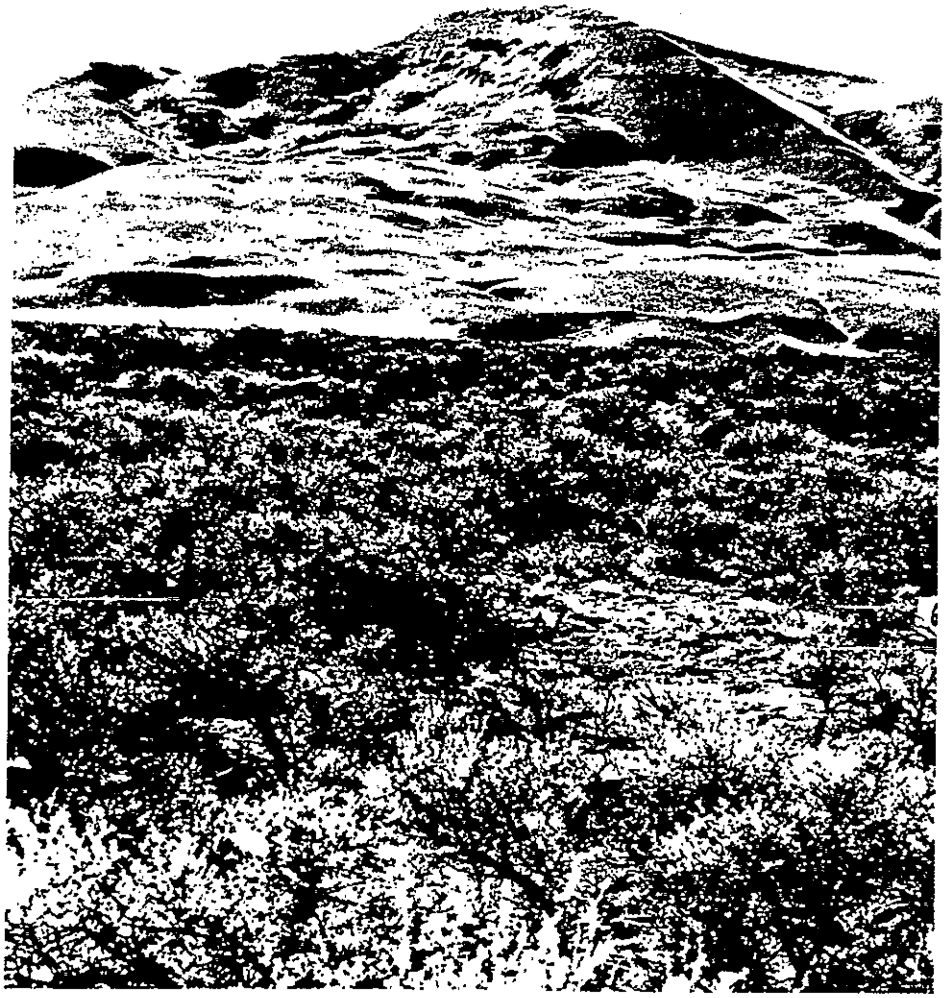

FIGURE II.3-G-9 SAGEBRUSH/SANDBERG'S BLUEGRASS COMMUNITY. (The shrub is big sagebrush and the sparse understory grass is Sandberg's bluegrass.)

Small mammals are abundant on the Hanford Reservation and their population dynamics have been studied by mark and recapture techniques in the sagebrush/bluebunch wheatgrass[23] and sagebrush/cheatgrass vegetation[24] and in the sagebrush-bitterbrush/cheatgrass vegetation.[25] The Great Basin pocket mouse is the most abundant mammal on the Reservation. Deer mice and ground squirrels are locally abundant, as is the pocket gopher. Other small mammals are the harvest mouse, house mouse, Norway rat, mountain vole, sagebrush vole, grasshopper mouse, vagrant shrew, Merriam shrew, least chipmunk, and woodrat. The kangaroo rat is not found on the Hanford Reservation although it is common in the steppe region of Oregon. (A species list of the mammals and other vertebrates that occur on the Reservation is provided in Part 3 of this Appendix.)

II.3-G.5 Birds

The chukar partridge is the most important upland game bird on the Hanford Reservation. Most of the population is concentrated on the ALE Reserve, especially the Rattlesnake Hills, but local populations exist in the Gable Mountain and White Bluffs area. Although introduced to Washington from Eurasia, the chukar is well adapted to the arid environment of the Hanford Reservation, feeding upon herbage, seeds and insects associated with dry rangeland.

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FIGURE II.3-G-12 WINTERFAT/SANDBERG'S BLUEGRASS COMMUNITY. (The short-statured shrub in the foreground is winterfat.)

The steppe region of south-central Washington is not rich in bird species. A year-long survey of the birds observed on and adjacent to waste ponds in the 200 Area showed 116 species.[27] The annual Christmas bird census by the Lower Columbia Basin Audubon Society registers about 80 species. Many species are migratory waterfowl and shorebirds; only a few species nest in steppe vegetation. The most abundant birds in steppe vegetation are the western meadowlark and the horned lark.[29] The most abundant nesting birds in the riparian vegetation include, among others, magpies, crows, doves, some warblers, and waterfowl.

II.3-G.6 Snakes and Lizards

As compared to the southwestern United States desert areas, the herpetofauna of the Hanford Reservation, like south-central Washington in general, is sparse. The most abundant reptile in low elevation steppe vegetation is the side-blotched lizard. The horned lizard is not common and the sagebrush lizard is scarce. The most abundant snake is the gopher snake, but the yellow-bellied racer and the Pacific rattlesnake are common. The coachwhip snake and the desert night snake are seldom observed.

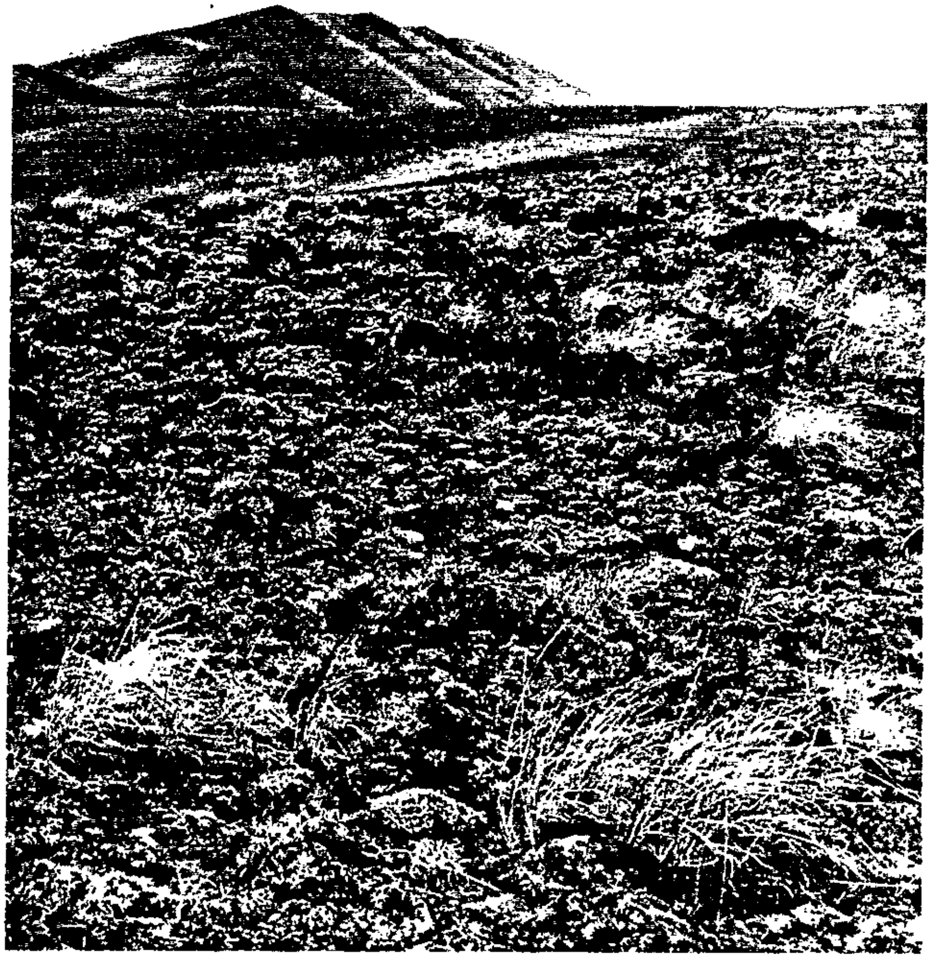


FIGURE II.3-G-13 THYME BUCKWHEAT/SANDBERG'S BLUEGRASS COMMUNITY. (Appearing at high elevations on the ALE Reserve, the low-growing cushion-like plants are thyme buckwheat.)

Snakes are an important food item for the Swainson's hawk. Most reptiles are rather widely distributed over the Hanford Reservation in small numbers, generally decreasing in numbers as elevation increases. The side-blotched lizard apparently does not occur at all at elevations above 400 meters.

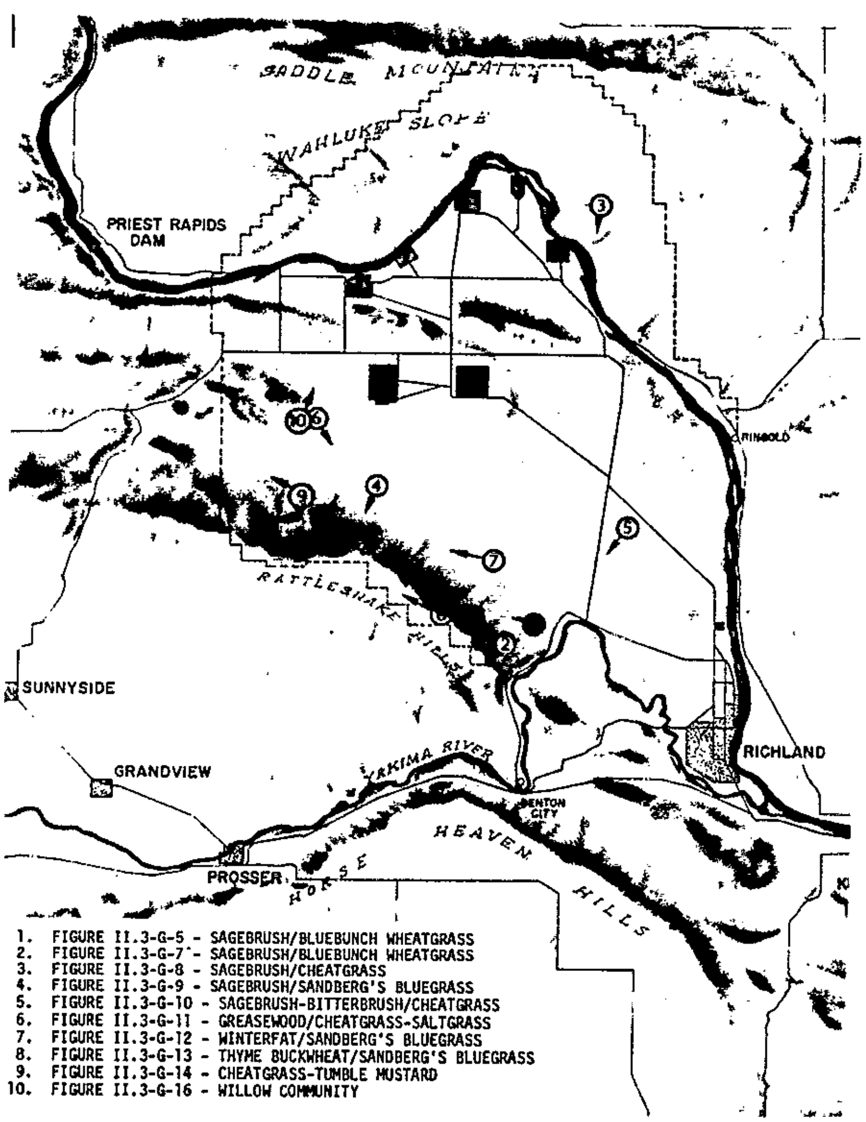
II.3-G.7 Insects

Insects on the Hanford Reservation, as everywhere else, are dependent upon plants for their livelihood. However, the vegetation in an area does more than provide food supporting associated invertebrate food webs; it also serves to modify extreme fluctuations of environmental conditions, such as temperature, humidity, and wind speed. An understanding of the influence plants exert on an area makes it easier to grasp how vegetation determines the kinds and abundance of insects.

FIGURE II.3-G-14 CHEATGRASS-TUMBLE MUSTARD COMMUNITY. (This occupies a 30-year old abandoned wheatfield at mid-elevation on the ALE Reserve.)

Two main phases of plant growth are on the Hanford Reservation; one occurs in the fall with the onset of winter rains. The ensuing burst of growth in some grasses lasts until cold weather precludes further growth. This is not a good time for insects, even though succulent plant material is available, because the onset of cold weather is frequently swift and unpredictable. An insect population emerging at this time would risk decimation by adverse conditions. The second period of rapid plant growth occurs in the spring, with the occurrence of warmer temperatures. This seems to be the period when insects are most abundant, their numbers reaching a peak in June and then declining as the plants become dormant in response to depletion of soil moisture. The months of July and August are another inhospitable time for insects--temperatures are high, humidity is low and few succulent plants are available. This does not mean that insects are not present; insects are always present, but at times in relatively small numbers.

A preliminary list of insect species known to inhabit this area is shown in Part 4 of this Appendix. Although the species which contribute significantly to insect abundance are contained in this list, this list will probably continue to be updated for several years as additional specimens are found. The following discussion will deal only with some of the important groups known to be present at the Hanford site--particularly where certain kinds of insects are found and their role in ecosystems functioning.



<u>FIGURE II.3-G-15</u> LOCATION AND DIRECTION OF VIEW FOR PLANT COMMUNITY PHOTOGRAPHS

Members of the order Homoptera are rather specialized plant eaters (herbivores). All members of this order have their mouth parts modified into a piercing beak and imbibe juices from the leaves, stems or roots of plants. Homoptera occur in relatively low numbers early in the season at Hanford and become more numerous as the season progresses, reaching a peak during the month of August. Leafhoppers (Cicadellidae), aphids (Aphididae) and plant hoppers (Fulgoridae) are all present, but members of the superfamily Coccidae are the most abundant. The Coccidae are primarily mealybug (Pseudococcidae), most of which occur in association with bluebunch wheat-grass, indicating that this grass may be a favored food source. Cicadas may periodically be conspicuously present in this area, primarily due to the buzzing "song" produced by the males. They may remain as larvae in the soil for several years, but the adult stage generally lasts only a few summer months.

The order Orthoptera contains the well known family Acrididae (grasshoppers) which are frequently very destructive members of grassland communities. The grasshopper possessing the greatest potential for outbreak in this area is the migratory grasshopper (<u>Melanoplus sanguinipes</u>). Under optimal environmental conditions, this species is able to increase from 100 female eggs to 8265 female eggs in one generation.[30] Localized concentrations have occurred at Hanford in the

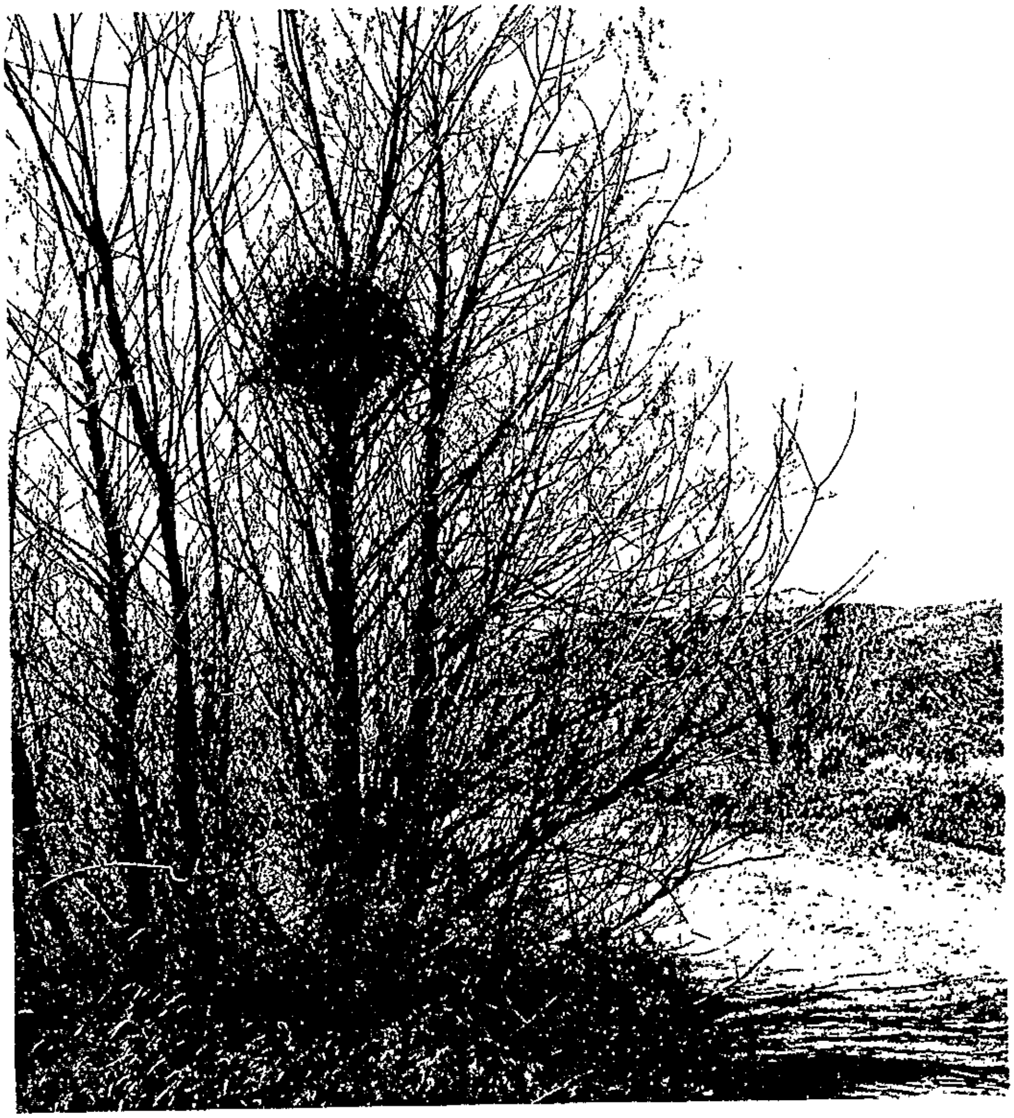


FIGURE II.3-G-16 WILLOW COMMUNITY. (Located at Rattlesnake Springs on the ALE Reserve.)

past[19] and will probably continue to do so in the future. These concentrations appear to occur only in the cheatgrass/tumble mustard vegetation. Soil disturbance, resulting in an invasion of cheatgrass, Russian thistle or goatsbeard, would provide an ideal area for the buildup of grasshopper populations.

The order Coleoptera (beetles) comprises the largest insect order and contains nearly 50 percent of all known insect species. A very diverse group, they inhabit nearly all conceivable types of habitat. Many are herbivores, some are predaceous, and others are scavengers, helping to break down organic residue for further decomposition--an important role in an arid ecosystem.

Some important predaceous beetle families in this area are the ground beetles (Carabidae), tiger beetles (Cicindelidae), checkered beetles (Cleridae) and ladybird beetles (Coccinellidae). The weevils (Curculionidae) are probably the most important group of plant eaters in this order. There are 16 species of darkling beetles known to occur in this area. Many species in this group function as scavengers--eating dead plant and animal matter. Two species of darkling beetle, Philolithus densicollis and Stenomorpha puncticollis, can be particularly abundant. These beetles emerge from the soil in the fall and spend the few months prior to cold weather feeding, mating, and depositing their eggs in the soil where immature beetles spend two years feeding and developing beneath the surface. These beetles have a "patchy" distribution, being very abundant in certain areas and much less abundant in other nearby locations. Philolithus does not occur in high elevation cheatgrass/tumble mustard vegetation, and is very much more abundant in native grasslands than in cheatgrass swards. Stenomorpha is somewhat less abundant than Philolithus, and less sensitive to vegetation type, but Stenomorpha does not occur at low elevations.

The order Hymenoptera (ants, wasps, bees) contain a great number of species that are either predators or parasites, as well as the plant pollinators essential for ensuring fertilization of many flowering plant species. The ants (Formicidae) are an important component of natural systems. Most are omnivores--taking both plant and animal material as food. They also perform a "tilling" of the soil through colony construction. Some colonies have tunnels penetrating to depths exceeding 10 feet. Soil from colony construction is deposited on the surface and organic materials (food) are taken into the colony, thereby enriching the soil. Ants are not abundant on the Reservation, but they seem to occur in all vegetation-types.

Members of the family Sphecidae are solitary wasps. Most nest in burrows constructed in the ground and provision the young with prey. The Ichneumonidae are another important Hymenopteran family, attacking a great variety of insect hosts. Unlike the sphecids who paralyze and then drag their prey to a burrow, the Ichneumons are mostly internal parasites of immature stages of the host. Wasps are very mobile and occur in all vegetation-types.

The collembola (springtails) play a dual role, some members feeding on decomposing plant material, others feeding directly on living plant tissue. Collembola are very common in any mulch layer but are frequently overlooked, due to their tiny size. Collembola populations at Hanford peak in early May and collect infrequently at other times. They appear to be associated with the crowns of bunchgrasses and with the litter layer that accumulates beneath sagebrush or cheatgrass. The most abundant collembola species belongs to the family Sminthuridae, sometimes called the globular springtails.

(The distribution of the abundant plants and animals in the several vegetation-types, arranged in order of decreasing elevation, is given in Part 5 of this Appendix. This listing demonstrates clearly that animals are more ubiquitous than plants.)

II.3-G.8 Rare or Threatened Species

Three endangered or threatened species of vascular plants are known to occur on the Reservation: Balsamorhiza rosea, Erigeron piperianus, and Eriogonum thymoides. All occur on the ALE Reserve rather than the low lands where waste management activities are planned. In addition, Allium robinsonii may occur in the gravel bars along the Columbia River; it also is noted as a threatened species.[40]

Reptiles and amphibians on the Reservation are restricted to a few wide-ranging species, none of which can be classified as rare, although the sagebrush lizard and the desert night snake are seldom seen at Hanford.

Mammals on the Reservation are not endangered at the species level, although their presence on the Reservation may be in very small numbers. Minks and bobcats are examples of low-density species.

Birds are a different matter. The Hanford Reservation provides a refugium for several rare, threatened or indeterminate species.[31] The prairie falcon (Falco mexicanus) nests in several regions on the Reservation, with the number of nesting pairs probably in the dozens.[28] The American peregrine falcon (Falco peregrinatus anatum) apparently does not nest on the Reservation but in the neighboring regions, probably in small numbers.[28] Species lacking specific data to attest to their status but considered to be possibly in some danger (i.e., indeterminate) include 1) the ferruginous hawk (Buteo regalis) which nests in several sites on the Reservation but in small numbers, 2) the American osprey (Pandion haliaetus carolinensis) only a visitor, 3) the western burrowing owl (Speotyto cunicularia hypugaea) and 4) the long-billed curlew (Numerius americanus). The last two nest on the Reservation in small but significant numbers.

II.3-G.9 Fragile or Restricted Microhabitats

The principal example of a fragile microhabitat on the Hanford Reservation is the few hectares of thin rocky soils on exposed ridgetops supporting the thyme buckwheat/Sandberg's bluegrass vegetation-type. On the Hanford Reservation, only the ALE Reserve has any extensive examples of this habitat, and its extent has been relentlessly reduced by construction activities over the past decades. The aspect of this vegetation-type is quite reminiscent of an alpine fell-field: small grasses, cushion-form forbs, and a great deal of bare rocky surface. Constant exposure to cold and desiccating winds without the protection of winter snows has pruned the vegetation toward cushion-form, even in normally erect species, a fact readily seen by comparing the stature of species common to rocky outcrops at lower elevations and ridgetops. An alpine cushion plant, Phlox hoodii, is as abundant in this community as on the alpine slopes of Mt. Hood. The slow growth characteristic of arid climates is accentuated in this habitat by poor water and mineral relations, so any area of disturbance is extremely slow to recover.

The Hanford Reservation encloses about 3000 hectares (12 square miles) of active sand dunes near the Columbia River about 8 kilometers south of the old White Bluffs townsite. Shifting, blowing sands in the dune areas combine a very porous substrate with placement in a most arid region to produce a very severe microhabitat populated by relatively few species. Colonizing species such as Psoralea lanceolata are rather common on the larger (hence slower-moving) dunes, but the smaller dunes only a meter or two high move so rapidly that colonization is much reduced. Scattered dunes of small stature exist in the lower elevations of the Hanford Reservation between the 200 Areas and the WYE Barricade; these dunes barely exceed a meter in height and may move hundreds of meters each year. Many of these small dunes were drowned under gravel at roadsides by maintenance crews to prevent them from inundating roads with sand. However, the large dunes near the river may be 15 or 20 meters high and move only a few meters each year, providing suitable footing for vigorous colonizing species. Although the dunes contain so much sand they cannot be rightly considered a restricted microhabitat, the dune's structural integrity and existence are sensitive to disturbance. For example, animal tracks over the crest of a Barchan (crescent) dune can split the dune into two smaller dunes which therefore travel faster than their larger neighbors, leading to overrunning and disappearance.[8]

Kettles and drumlins exist in small areas near the 100-N Area (N Reactor site) on the Reservation. These small mounds and depressions are very rocky, with little fine soil, and are covered with a low-growing vegetation comprised mostly of small annuals, such as cheatgrass, Microsteris and Sandberg's bluegrass. The improved water relations on north-facing exposures of these small mounds can cause notable differences in species presence and abundance.

The dispersal of aqueous effluents to the ground surface formed permanent ponds in the 200 Areas. Over the past quarter of a century, vegetation has changed in response to the change in soil moisture. Aquatic emergent species, i.e., cattail and bulrush, grow in most of the ponds. Shrub and tree willows are becoming well established along pond shores, as are mesic plants such as barnyard grass, reed canary grass, cudweed, white top, Russian knapweed, goldenrod, milkweed, and others. These plants often form dense stands that provide food and cover for wildlife and nesting places for song birds and raptors that were not present before the formation of the ponds.

A few tiny areas of essentially pristine low elevation shrub-steppe vegetation exist along north-facing slopes of ancient dune trails on and below the 200 Area plateaus. The undisturbed nature of these small areas is testified to by the complete absence of cheatgrass, which in general abounds in these lower elevations. The slightly more favorable microenvironments on north-facing slopes has allowed mosses and other bryophytes to maintain a nearly continuous soil cover, thus preventing wind erosion of the sandy soils (which would provide the disturbed soil surface favoring cheatgrass). In these small areas, the spaces between sagebrush individuals are carpeted almost completely with either bryophytes or bunches of Sandberg's bluegrass, and are annually attired in the full regalia of desert flowers, principally Phlox.

A few sites exist on north exposures at higher elevations that have a relatively deep wind-deposited soil supporting a grassland reminiscent of shortgrass prairie (true steppe) and very similar to the Palouse grasslands of southeastern Washington before agriculture embraced them. A steep north exposure provides improved water relations by capturing windblown snow and shielding the community from desiccating winds and intense sunshine. A dense grass cover with no interstices between grass clumps is the result, including an interspersion of a few specimens of shrubs typical of more mesic (gentler) habitats, such as snowberry.

The eastern shoreline of the Columbia River is marked by steep-walled banks of 100 meters or more in height. These banks are marked on topographic maps as "White Bluffs." Historically, these banks have provided nesting sites for thousands of pairs of breeding swallows (cliff swallows and bank swallows) and a few nests of the prairie falcon. Occasionally Canada geese have also built nests on narrow ledges. In recent years the bluffs have provided nest sites for flocks of feral rock doves (pigeons) and starlings.

II.3-G.10 Pest Animal Species

House mice (Mus Musculus) and the Norway rat (Rattus norvegicus) are occasionally trapped away from buildings. House mice have been trapped in the riparian vegetation at Rattlesnake Springs and along the Columbia River.

Starlings occasionally occur in large flocks, especially in winter. A few nesting pairs have been observed in hollow trees at Rattlesnake Springs and Snively Ranch on the ALE Reserve.

II.3-G.11 Plants

II.3-G.11.1 Primary Productivity

Arid and semi-arid lands are not as biologically productive as humid or wet lands (Table II.3-G-4). Deserts produce on an annual basis less than 0.2 grams of herbage per square meter per day. The annual aboveground herbage production has been determined on the Hanford Reservation in cheatgrass and in shrub-grass communities. A summary of the peak live standing crop of three different cheatgrass communities on the ALE Reserve over the last 5 years is shown in Table II.3-G-5. Over the 5-yr period annual herbage yields ranged between 107 and 328 g/m^2.

TABLE II.3-G-4

ANNUAL PRODUCTIVITY ESTIMATES FOR VARIOUS ECOSYSTEMS
(g/m^2)

Ecosystem	Productivity
Spartina salt marsh	3300
Pine plantation	3180
Deciduous forest	1560
Tall grass prairie	446
Short grass prairie	69
Desert	40

TABLE II.3-G-5

PRODUCTIVITY OF OLD-FIELD (CHEATGRASS-TUMBLE MUSTARD)
COMMUNITIES, 1969-1973
(g/m^2)

Elevation in Meters	180	305	518
1969	328 $\pm$ 28	327 $\pm$ 26	226 $\pm$ 15
1970	165 $\pm$ 11	127 $\pm$ 8	208 $\pm$ 20
1971	Not Avail.	211 $\pm$ 11	263 $\pm$ 38
1972	Not Avail.	132 $\pm$ 7	107 $\pm$ 12
1973	Not Avail.	205 $\pm$ 15	226 $\pm$ 35
Average	246	200	206

Over the years cheatgrass communities have produced on an annual basis more herbage than sagebrush-grass communities. The productivity of pristine stands of sagebrush-bunchgrass is considered[1] to be about 100 g/m^2. On the ALE Reserve, production of herbage in a sagebrush-grass community has been somewhat more than that in recent years (Table II.3-G-6).

Pronounced differences in species diversity are observed between cheatgrass communities and the sagebrush-grass communities, demonstrated in Table II.3-G-7. Nine species of plants contribute to the herbage yield of cheatgrass communities, eight of which are annuals. About 20 species contribute to plant biomass in the sagebrush-grass community, mostly perennials of several different life forms.

TABLE II.3-G-6

PRODUCTIVITY OF A SAGEBRUSH-
BLUEBUNCH WHEATGRASS COMMUNITY
(g/m^2)

Year	Herbage	Sagebrush	Total
1971	63 ± 4	53 ± 11	116 ± 15
1972	65 ± 14	55 ± 36	120 ± 50
1973	51 ± 5	42 ± 19	93 ± 24

TABLE II.3-G-7

SPECIES DIVERSITY IN CHEATGRASS AND SAGEBRUSH/GRASS COMMUNITIES

Cheatgrass Community		Sagebrush-Grass Community	
Taxa	Life Form	Taxa	Life Form
Cheatgrass	ANGR	Sagebrush	SH
Sandberg bluegrass	PEGR	Longleaf phlox	PEFO
Tumble Mustard	ANFO	Fleabane	PEFO
Tansy mustard	ANFO	Bluebunch wheatgrass	PEGR
Jagged chickweed	ANFO	Sandberg bluegrass	PEGR
Filaree	ANFO	Needlegrass	PEGR
Spring draba	ANFO	Cusick's poa	PEGR
Lanceleaf microseris	PEFO	Cluster lily	PEFO
Yellow Salsify	PEFO	Sego lily	PEFO
		Six weeks fescue	ANGR
		Hawk's beard	PEFO
		Lupine	PEFO
		Locoweed	PEFO
		Spring draba	ANFO
		Pussy Toes	PEFO
		Daisy	PEFO
		Yarrow	PEFO
		Indian paintbrush	PEFO
		Plantago	ANFO
		Tansy Mustard	ANFO

CODING

ANGR = Annual Grass
ANGO - Annual Form
PEFO - Perennial Forb
PEGR = Perennial Grass
SH = Shrub

Although herbage production is the visible output of plant growth, a root system is also produced each year. A comparison of root biomass and distribution in the soil profile of cheatgrass and sagebrush-grass communities is shown in Figure II.3-G-17. Less than 25% of the root biomass in the cheatgrass community is deeper than 2 decimeters, compared to 50% for the sagebrush-grass community. The total biomass is also greater in the sagebrush-grass community compared to the cheatgrass community, i.e., 1200 versus 800 g/m^2. However, the root biomass data consist of a mixture of living and dead roots because to separate live roots from dead roots from soil cores is not practical.

II.3-G.11.2 Mineral Uptake

Herbage provides a source of energy, protein and essential minerals for herbivorous animals, but the amount of energy available to consumers is quite variable. Table II.3-G-8 shows the average heats of combustion (total heat release or caloric content) of cheatgrass, tumble mustard, bluebunch wheatgrass, Sandberg's bluegrass, and sagebrush leaves and flowers. The mustard has a

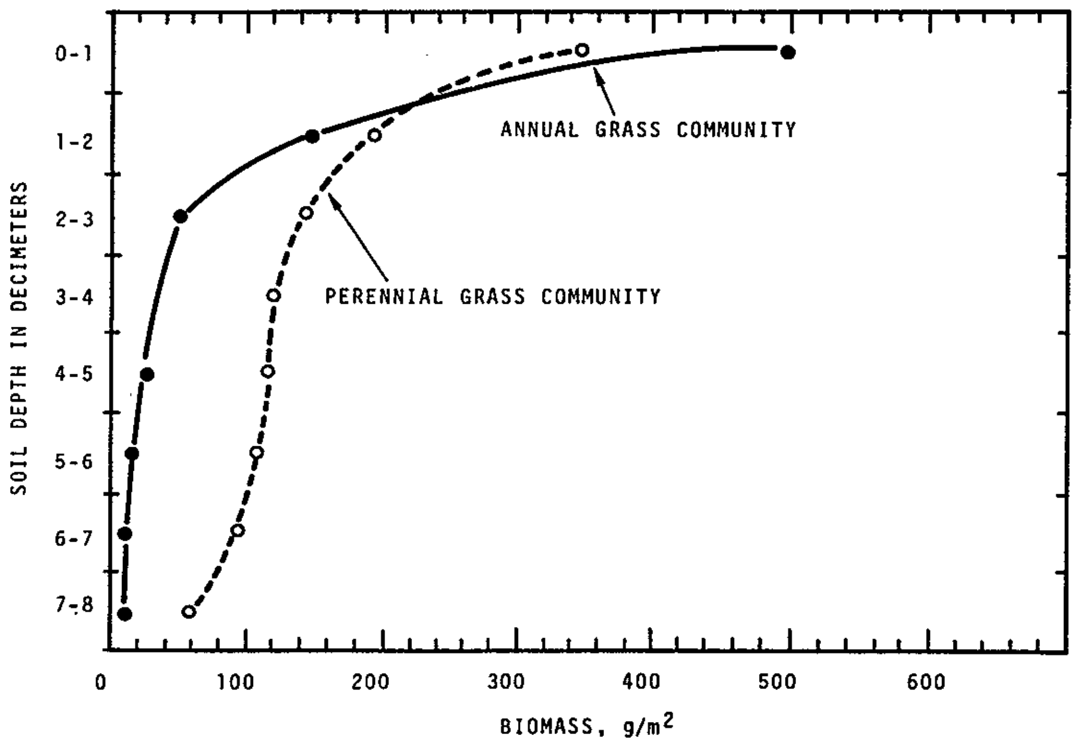


FIGURE II.3-G-17 DISTRIBUTION OF ROOT MATERIAL WITH DEPTH IN PERENNIAL AND ANNUAL GRASS COMMUNITIES

significantly higher amount of energy bound up in its tissues than the other species, while the grasses have the least, typical of comparisons between broad-leaved plants and grasses. Although a crude measure of energy such as this does not measure usable energy, the relative contribution of the various species to digestible energy is probably similar.

However, the importance of plants to consumers involves much more than as a source of energy. Plants extract minerals from the soil solution for their own functioning, making these minerals available for consumer organisms. Of particular interest to radiation ecology is the amount of stable mineral elements that plants obtain from the soil in which they grow. The mineral elements present in cheatgrass and bluebunch wheatgrass are shown in Table II.3-G-9.

Some plants accumulate mineral elements to significant concentrations;[15] the results of chemical analysis of greasewood and hopsage leaves growing in the same plant community are shown in Table II.3-G-10.

II.3-G.12 Litter Decay and Mineral Cycling

Continuous maintenance of life requires that mineral nutrients currently bound up in plant and animal life eventually be returned to a common nutrient pool for use by succeeding generations. The rate of return is mostly governed by the activity of microflora and microfauna, organisms of

TABLE II.3-G-8

HEATS OF COMBUSTION OF SEVERAL SPECIES ON THE HANFORD RESERVATION
Kilocalories gram^{-1} (Dry Weight)

Species	Cheat-grass	Tumble mustard	Wheat-grass	Blue-grass	Sagebrush Flowers and Leaves
Heat of Combustion	3.8	6.1	3.9	4.2	4.8

TABLE II.3-G-9

MINERAL ELEMENTS IN CHEATGRASS AND BLUEBUNCH WHEATGRASS

	Cheatgrass	Bluebunch Wheatgrass
N, %	1.7	0.92
P, %	0.25	0.15
K, %	1.6	0.67
Ca, %	0.60	0.32
Mg, %	0.18	0.08
S, %	0.25	0.11
Na, %	0.06	0.03
Zn, ppm	20	7.2
Cu, ppm	6	1.1
Fe, ppm	700	130
B, ppm	20	9.4
Mn, ppm	80	77

TABLE II.3-G-10

ACCUMULATION OF MINERALS IN DESERT SHRUB FOLIAGE

	Na %	K %	Ca %	Mg %
Greasewood	12	2.5	1.5	0.5
Hopsage	0.6	11	1.9	1.6

decay which live on or in dead biotic material. The metabolic activity of these microbiota (measured by CO_2 evolution from the soil) is rather closely attuned to environmental conditions of temperature and moisture.[32] High levels of both temperature and water induce high levels of soil CO_2 evolution, but the climate of the Hanford Reservation precludes such coincidence in general. Consequently, soil CO_2 evolution is usually low, implying relatively little microbiotic activity compared to a humid climate.

The rate of return of biotically fixed minerals is shown in Figure II.3-G-18 for cheatgrass in the cheatgrass/tumble mustard vegetation-type and for sagebrush leaves in the sagebrush/cheatgrass vegetation-type. Decomposition of the annual grass, cheatgrass, can be considered in three phases following its peak standing crop in May: first, the loss of seeds during summer; second, the transition from standing dead (with essentially no potential for decomposition) to flat litter in intimate contact with the soil biota; and third, the relatively slow continuous disappearance of the flat litter. Measurements of loss from litter bags over a 2-yr period indicated that phase III can be accurately considered an exponential process with a half-time of 6 ± 1 years. This is much slower than the 1 to 2-yr half-time noted for the perennial bluebunch wheatgrass. Similar measurements in the humid tall grass prairie of Missouri[33] also indicated a disappearance half-time of about 1.5 year for perennial grass litter in Missouri.

Sagebrush casts about 90% of its leaf biomass in early summer, presumably a period of relatively slow decomposition, but weight losses from litter bags are noted[34] (as shown in Figure II.3-G-18) implying a half-time of about 1 year, very much faster than cheatgrass leaves and stems. However, leaf and influorescence litter, which is the annual portion of sagebrush biomass, comprises only about a half of 1% of the total standing crop. No detectable weight losses of bark, branches, and buried roots occurred even after 2-1/2 years,[34] indicating that minerals in these portions of the sagebrush community remain unavailable for a relatively very long time.

II.3-G.13 Animal Populations

Most of the animals on the Hanford Reservation are nongame species having no direct link to man through the food he eats. However, these animals provide food for predators. Some of the most abundant animals on the Hanford Reservation in terms of biomass (g/m^2) are darkling beetles, which can attain an estimated peak biomass of 2 gm m^{-2} (20 pounds per acre) in cheatgrass communities.[35] These beetles can provide an important food supply for some predators in autumn when beetles are active on the soil surface for a few weeks.[36]

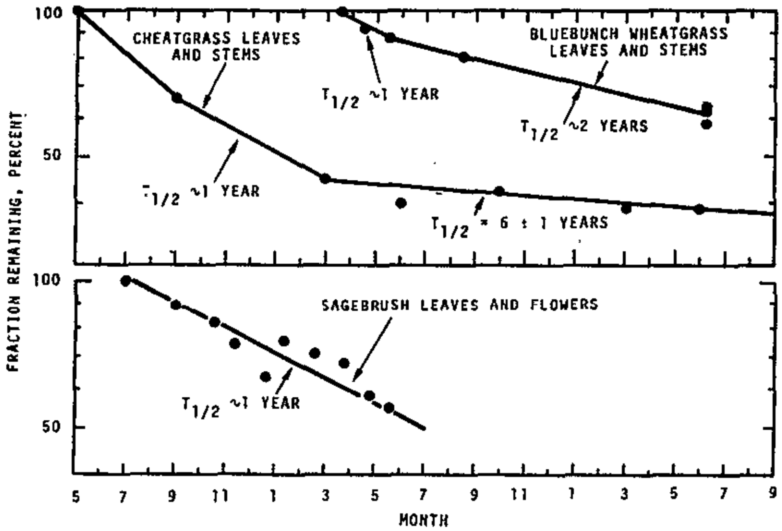


FIGURE II.3-G-18 RATE OF WEIGHT LOSS IN LITTER BAGS OF LEAVES AND STEMS OF CHEATGRASS, SAGEBRUSH AND BLUEBUNCH WHEATGRASS

Coyotes are wide-ranging animals that have the potential for wandering on and off the Hanford Reservation boundaries in search of food. Coyotes have disrupted the nesting of Canada geese on Columbia River islands.[26] No studies on the Hanford Reservation have been conducted to determine the population densities or movements of the coyote, but an aerial patrol is maintained for the ALE Reserve and casual coyote sightings are recorded. The number of coyotes seen from 1969-1973 are shown in Table II.3-G-11 but how many of these values represent repeated sightings of the same animals is not known.

TABLE II.3-G-11

COYOTE SIGHTINGS BY AERIAL PATROL

Year	1969	1970	1971	1972	1973
Sightings	9	6	16	14	13

The relative freedom from "people use" has made the Hanford Reservation an attractive nesting refuge for large raptors. A scarcity of suitable places to build nests is one of the reasons for low density nesting populations of Swainson's and red-tailed hawks.[28] Marsh hawks, sparrow hawks, prairie falcons, burrowing owls and great-horned owls are known to nest on the Hanford Reservation. The golden eagle, bald eagle and osprey frequent the Hanford Reservation in winter as a foraging ground.

The mule deer and the Canada goose are the most important game species that use the Columbia River area as a breeding ground. Both rely heavily upon the relative security of the islands in the Columbia River as a sanctuary for rearing young. Over the past 4 years 180 mule deer fawns were tagged near the Columbia River and released; 17 tags have been returned from legal kills and road kills, etc., some from more than 4 miles from the tagging site.[22]

A 21-yr history of Canada goose nesting on the islands is shown in Figure II.3-G-19. The recent decline in numbers was attributed to coyote predation during nesting.[26] Over the study period, Hanford's nesting geese had 97.4% fertility, equal to or better than areas that do not have operating nuclear reactors nor chemical separations facilities.

The Great Basin pocket mouse is, in terms of number per acre, the most abundant mammal on the Hanford Reservation. Studies using mark-release techniques show that pocket mice spend their entire lives in a small area. The number of mice in a 6.8 acre plot in a sagebrush-grass community varies considerably from year to year, as shown in Figure II.3-G-20. The relative numbers of various species in the community are shown in Table II.3-G-12.[23]

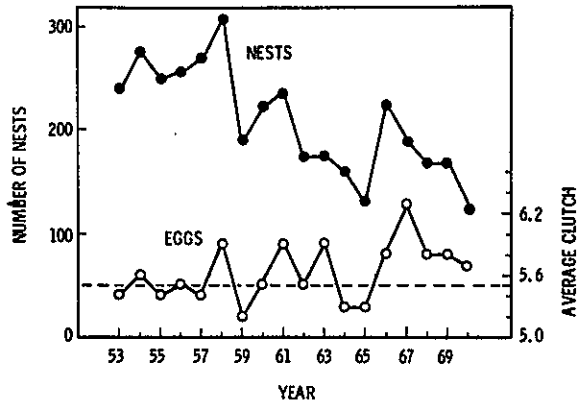


FIGURE II.3-G-19 NUMBER OF NESTS AND NUMBER OF EGGS PER NEST FOR CANADA GEESE NESTING ON ISLANDS IN THE COLUMBIA RIVER, HANFORD RESERVATION

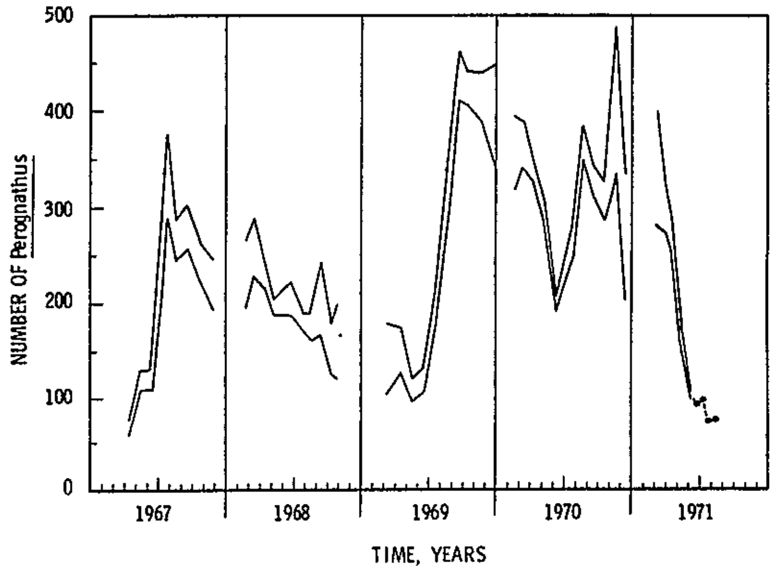


FIGURE II.3-G-20 POPULATION FLUCTUATIONS OF THE POCKET MOUSE, PEROGNATHUS PARVUS, IN A SAGEBRUSH/CHEATGRASS COMMUNITY

II.3-G.14 Food Webs

Earlier pages have discussed briefly some aspects of the distribution of environmental factors on the Hanford Reservation and the subsequent distribution of plants and animals. Another section was denoted to considering population numbers and fluctuations on the Reservation, as opposed to distribution in space. However, the dynamic interplay of the many organisms can best be grasped by considering the rates and routes of energy transfers between the species...the "fate and effects" of food in the ecosystem. Following is a synthesis of ecological transfers on the Hanford Reservation, based on a few representative organisms and interactions, beginning with potential transfers to man, then considering a non-anthropocentric ecosystem.

II.3-G.14.1 Transfers to Man

Historically, the unmodified steppe ecosystem of southern Washington provided relatively little food to man. Indian tribes relied mostly upon Columbia River fishes as a food base. Apparently, steppe vegetation did not support bison nor antelope herds. Cattle and sheep grazing provided a

TABLE II.3-G-12

SMALL MAMMALS TRAPPED IN A SAGEBRUSH/CHEATGRASS COMMUNITY, 1972

Month	Pocket Mouse	Deer Mouse	Ground Squirrel	Grasshopper Mouse
Jan	0	5	0	1
Mar	33	11	12	3
Apr	48	7	38	1
May	41	2	20	0
June	44	2	3	1
July	35	0	0	0
Sept	30	1	0	1
Nov	2	0	0	2

food base for man, but the most arid parts of the steppe region were not very productive, and overgrazing resulted in marked changes in floristic composition.

Irrigation is a practical way to modify steppe lands to agriculturally productive acreage. However, the unmodified steppe ecosystem at Hanford provides little food for man. Livestock grazing is not practiced; mule deer forage to some extent upon steppe vegetation, but rely mostly upon riparian vegetation for food and cover. Since deer are mobile animals, some animals that are born on the Reservation are harvested off the Reservation by hunters.[22] The chukar partridge is the most abundant game bird that can subsist on the food and cover provided by unmodified steppe vegetation. Although chukar partridges are not hunted on the Reservation, hunting is common in the Rattlesnake Hills, Yakima Ridge and the Saddle Mountains.

Duck and goose hunting is a popular outdoor sport in Benton County, Washington, so ducks and geese are biota with potential contributions to food chains leading to man. Within the Hanford Reservation, a few ducks use cooling wastewater ponds to rear their young, but most of the utilization of ponds by waterfowl is during the fall migration period.[27] Hunting is not permitted on the Hanford Reservation on the plant side of the river, so this area serves as a refugium for ducks and geese during the hunting season. During the peak week of use in 1972, 1,100 ducks and geese were on Hanford ponds and 70,000 on the Hanford reach of the Columbia River.

II.3-G.14.2 Food Webs in a Steppe Ecosystem

Figure II.3-G-21 demonstrates the motivation for discussing food webs rather than chains, because typically a consideration of "who eats whom" will result in many linked transfers rather than a simple linear cascade of matter and energy through the ecosystem. Similar webs could be constructed around each plant species on the Reservation. Figure II.3-G-21 shows a web of energy and nutrient transfers centering on cheatgrass. Although inadvertently introduced to this region, this grass is well adapted to the Hanford climate.[3] Its success does not stem from a highly efficient capture of energy from the sun, but physiologically, it is geared for growth under the cool conditions concurrent with Hanford's wet season. Consequently, green cheatgrass appears (as seedlings) when few perennials are growing, making it desirable forage for a wide variety of animals, including mule deer, coyotes, and chukars. Mature cheatgrass seeds form important food sources for pocket mice and birds. The dead leaves and stems support a large number of microbiota, including mites, insects, nematodes and fungi.

Larger food items support larger consumers; Figure II.3-G-22 centers on chukar partridges, a bird with average adult biomass somewhat less than a kilogram. The chukar, in common with many birds, is opportunistic in its choice of diet, employing food items in their period of seasonal abundance: both plant and animal matter come to its attention. Chukars support avian predators like the prairie falcon, and scavengers like the magpie, at differing points in its life cycle. Likewise, mammalian and reptilian predators take advantage of its immobile reproductive stages--brooding hens and her eggs.

Insect predators abound in an arthropod-size community, as indicated in Figure II.3-G-23, which centers on grasshopper. However, insect predators are not alone, because even large mammalian predators will consume grasshoppers when the insect is abundant. Some reptiles also consume grasshoppers, as do small mammals; many carnivorous birds, including large raptors, depend upon insects for prey.

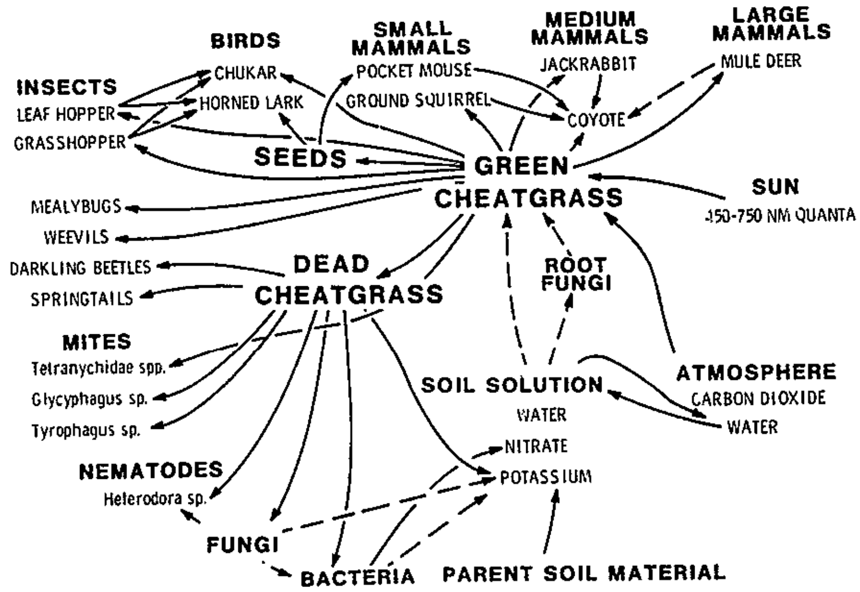


FIGURE II.3-G-21 FOOD WEB CENTERED ON CHEATGRASS (Arrows indicate direction of energy and mass transfer)

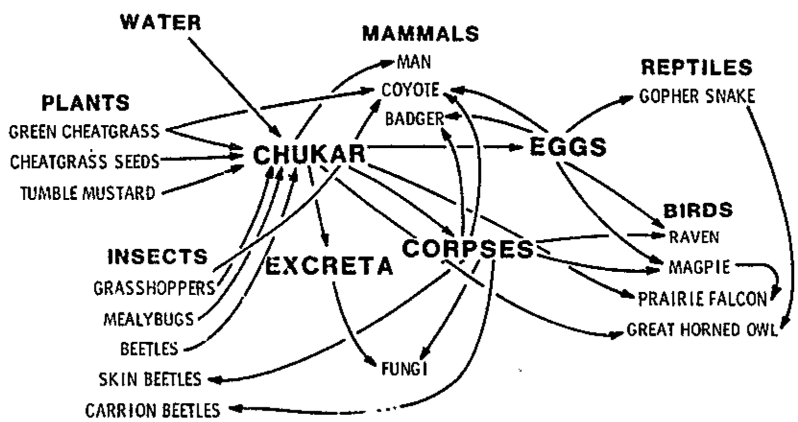


FIGURE II.3-G-22 FOOD WEB CENTERED ON CHUKAR PARTRIDGE (Arrows indicate direction of energy and mass transfer)

Two common notes are to be found in the preceding diagrams: 1) the edges of the webs involve the same top carnivores--coyotes, eagles, owls, etc.--and 2) all webs have a transfer into the microbiota, represented by the transfer to fungi. Figure II.3-G-24 diagrams a web centering upon fungi in general, not a particular fungal species. Microbiota are critical for continuous functioning of an ecosystem, but generally they are difficult to discuss with the same degree of concreteness as the larger organisms. Their small size is associated with high metabolic rate, so the individuals (and species) increase and decline very rapidly compared to the human norm of consciousness. Representative species of fungi are therefore not readily chosen.

Figure II.3-G-24 differs from the preceding diagrams in fundamental ways: 1) the transfers nearest to the fungal organism are more nearly a chain than those for macrobiota, 2) there are very many more dashed lines, indicating ignorance or uncertainty in many of the transfers, and 3) many members of the web are identified by family or superfamily rather than genus or species. These problems arise because this food web is extraordinarily difficult to study: the organisms are small, transient, hard to identify and difficult to observe in action.

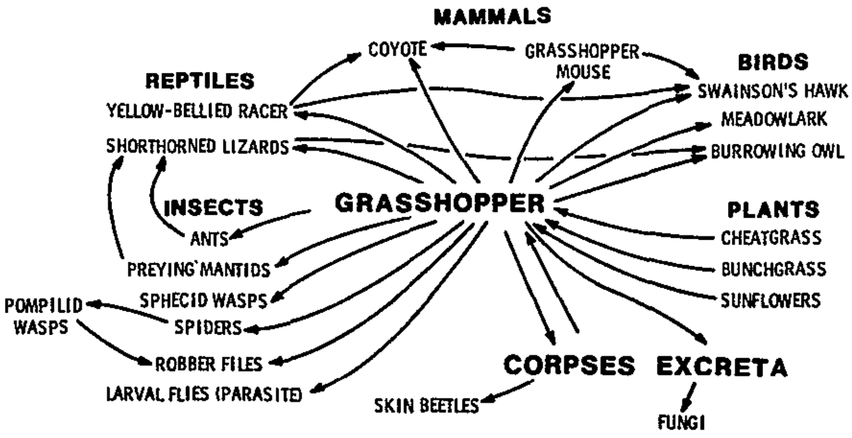


FIGURE II.3-G-23 FOOD WEB CENTERED ON GRASSHOPPER (Arrows indicate direction of energy and mass transfer)

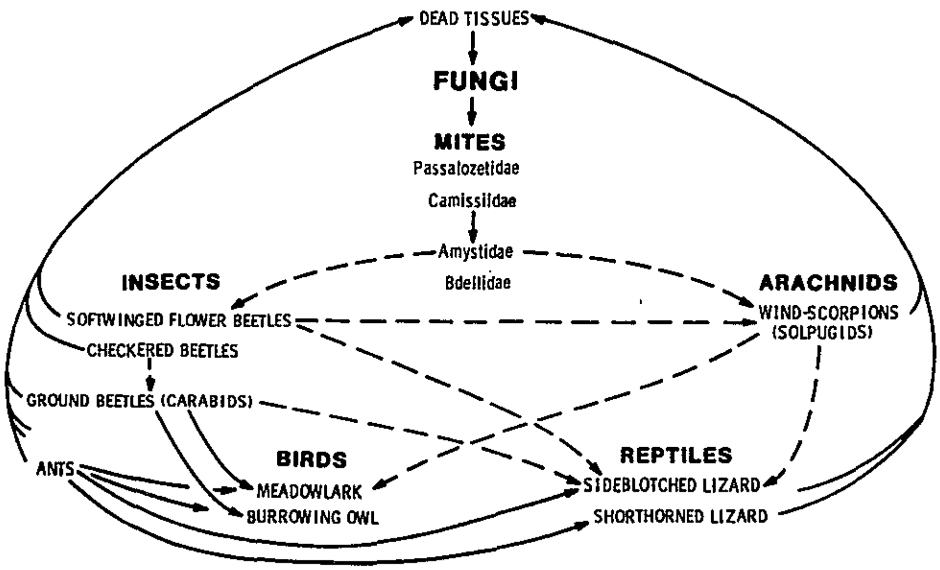


FIGURE II.3-G-24 FOOD WEB CENTERED ON FUNGI (Arrows indicate direction of energy and mass transfer)

II.3-G.15 Ecological Research Results and Availability

The preceding pages summarized some aspects of the ecological systems of the Hanford Reservation; more could have been written based on the many years of research at Hanford. A current and complete bibliography of journal articles, annual reports, Battelle documents and other writings by the staff of the Ecosystems Department is available.[37] Many of the references in that bibliography devolve directly from ecological research on the Hanford Reservation.

Good bibliographies of (world-wide) publications concerning ecological aspects of radioactive waste management are available, both for radioactive waste in general[38] and for transuranics[39] specifically.

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APPENDIX II.3-G, Part 2

<u>Vascular Taxa of the Hanford Reservation</u>

EQUISETACEAE	**Horsetail Family**	
Equisetum arvense L.		Common horsetail
JUNCACEAE	**Rush Family**	
Juncus torreyi Cov.		Torrey's rush
Juncus tenuis Willd. probably var. tenuis		
CYPERACEAE	**Sedge Family**	
Carex spp.		
Carex douglasii Boott.		Douglas' sedge
Eleocharis palustris (L.) R. & S.		Common creeping spike-rush
Scirpus americanus Pers.		Bulrush
Scirpus validus Vahl		Tule, soft stem bulrush
GRAMINEA	**Grass Family**	
Agropyron cristatum (L.) Gaeutnt.		Crested wheatgrass
Agropyron dasystachyum (Hook) Scribn.		Thick-spike wheatgrass
Agropyron spicatum (Pursh.) Scribn. & Smith		Bluebunch wheatgrass
Agropyron spicatum var. spicatum (Pursh.) Scribn. & Smith		Awned bluebunch wheatgrass
Agrostis exarata Trin.		Bentgrass
Bromus tectorum L.		Cheatgrass
Bromus sp.		
Distichlis stricta var. dentata (Rydb.) C.L. Hitchc.		Salt grass
Echinochloa crusgalli (L.) Beauv.		Large barnyard grass
Elymus cinereus Scribn. & Merrill		Ryegrass
Elymus glaucus Buckl.		Wild rye
Festuca bromoides L.		Barren fescue
Festuca idahoensis Elmer		Idaho fescue
Festuca microstachys Nutt.		Nuttall's fescue
Festuca octoflora		Six weeks fescue
Hordeum jubatum L.		Foxtail; Barley
Melica spectabilis		Onion grass
Oryzopsis hymenoides (R. & S.) Ricker		Indian ricegrass
Poa bulbosa L.		Bulbous bluegrass
Poa cusickii Vasey		Cusick bluegrass
Poa juncifolia Scribn.		Alkali bluegrass
Poa palustris L.		Fowl bluegrass
Poa sandbergii Vasey		Sandberg bluegrass
Polypogon monspeliensis (L.) Desf.		Rabbitfoot grass
Secale cereale L.		Rye
Setaria lutescens (Wiegel) Hubb.		Bristlegrass
Sitanion hystrix (Nutt.) J.G. Smith		Bottlebrush squirrel-tail
Sitanion hystrix var. hordeoides (Suksd.) C.L. Hitchc.		
Stipa comata Trin. & Rupr.		Needle & thread grass
Stipa thurberiana Piper		Needlegrass
Triticum aestivum L.		Wheat
TYPHACEAE	**Cat-tail Family**	
Typha latifolia L.		Cattail
LEMNACEAE	**Duckweed Family**	
Lemna minor L.		Duckweed
LILIACEAE	**Lily Family**	
Allium acuminatum Hook		Wild onion
Allium macrum Wats.		Wild hyacinth
Brodiaea douglasii Wats.		Howell's brodiaea
Brodiaea howellii Wats.		Sego lily
Calochortus macrocarpus Dougl.		Yellow bell
Fritillaria pudica (Pursh.) Spreng		False Solomon's Seal
Smilacina stellata (L.) Desf.		Death camas
Zigadenus paniculatus (Nutt.) Wats.		
POLYPODIACEAE	**Common Fern Family**	
Woodsia oregana D.C.		Wood fern
SALICACEAE	**Willow Family**	
Populus alba L.		White poplar
Populus tremuloides Michx.		Aspen
Populus trichocarpa T. & G. ex Hook		Cottonwood
Salix spp.		Willow
ULMACEAE	**Elm Family**	
Elmus pumila		Siberian elm
URTICACEAE	**Nettle Family**	
Urtica dioica var. gracilis L.		Stinging nettle
SANTALACEAE	**Sandalwood Family**	
Comandra umbellata var. pallida (D.C.) M.E. Jones		Bastard toad flx

POLYGONACEAE	Buckwheat Family	
Eriogonum heracleoides Nutt.		Parsnip flowered eriogonum
Eriogonum microthecium Nutt.		Slenderbush buckwheat
Eriogonum niveum Dougl. ex Benth.		
Eriogonum sphaerocephalum Dougl. ex Benth.		Roundhead
Eriogonum strictum var. flavissimum Benth.		
Eriogonum strictum var. proliferum		
Eriogonum thymoides Benth. in DC.		Thyme-leaved buckwheat
Rumex crispus L.		Sour dock
Rumex venosus Pursh.		Veined dock
CHENOPODIACEAE	Goosefoot Family	
Atriplex rosea L.		Red saltbush
Bassia hyssopifolia (Pall.) Kuntze.		
Chenopodium leptophyllum (Moq.) Wats.		Slender leaved goosefoot
Eurotia lanata (Pursh.) Moq.		Winterfat
Grayia spinosa (Hook.) Moq.		Spiny hopsage
Salsola kali L.		Tumbleweed
Sarcobatus vermiculatus (Hook.) Torr.,		Greasewood
AMARANTHACEAE	Amaranth Family	
Amaranthus albus L.		Pigweed
PORTULACACEAE	Purslane Family	
Lewisia rediviva Pursh.		Bitterroot
Montia perfoliata (Dorn) Howell		Miner's lettuce
Talinum spinescens Torr.		Fameflower
CARYOPHYLLACEAE	Pink Family	
Arenaria franklinii Dougl. ex Hool.		Sandwort
Holosteum umbellatum L.		Jagged chickweed
Silene douglasii Hook.		Campion; Catchfly
Silene menziesii Hook.		Menzies' silene
RANUNCULACEAE	Crowfoot Family	
Clematis ligusticifolia Nutt. in T. & G.		Virgin's bower' vase flower
Delphinium nuttallianum Pritz. ex Walpers		Larkspur
Myosaurus apetalous		Mouse-tail
Ranunculus glaberrimus Hook.		Smooth western buttercup; Sagebrush buttercup
Ranunculus sceleratus L.		Celery leaved buttercup
Ranunculus testiculatus Crantz		Horn seed buttercup
CRUCIFERAE	Mustard Family	
Arabis cusickii Wats.		Cusick's rockcress
Arabis holboellii Hornem.		Holboell's rockcress
Arabis sparsiflora Nutt. in T. & G.		Sicklepod rockcress
Cardaria draba (L.) Desv.		Heart-podded hoarycress; White top
Chorispora tenella (Pall.) DC.		Blue mustard
Descurainia pinnata (Walt.) Britt.		Western tansy mustard
Descurainia sophia L. Webb		Flixweed
Descurainia sp.		
Draba verna L.		Spring whitlow grass
Erysimum asperum (Nutt.) DC.		Rough wallflower; Prairie rocket
Lepidium perfoliatum L.		Pepper grass
Phoenicaulis cheiranthoides		Dagger pod
Rorippa nasturtium aquaticum (L.) Schinz & Thell.		Watercress
Sisymbrium sp.		
Sisymbrium altissimum L.		Tumblemustard
Streptanthella longirostris		
Thelypodium laciniatum (Hook.) Endl.		Thick-leaved thelypody
CAPPARIDACEAE	Caper Family	
Cleome lutea Hook.		Bee plant; Stinking mustard
CRASSULACEAE	Stonecrop Family	
Sedum leibergii Britt.		Leiberg's stonecrop
SAXIFRAGACEAE	Saxifrage Family	
Heuchera cylindrica Dougl. ex Hook.		Alumroot
Lithophragma bulbifera Rydb.		Bulbiferous fringe
Lithophragma glabra Nutt. T. & G.		Fringe cup
Lithophragma parviflora (Hook.) Nutt. ex T. & G.		Smallflower fringe cup
Saxifraga integrifolia var. claytoniaefolia (Canby) Rosend.		
Saxifraga sp.		
GROSSULARIACEAE	Current Family	
Ribes aureum Pursh.		Golden current; Yellow squawberry
Ribes cereum Dougl.		Red current

HYDRANGEACEAE	Hydrangea Family	
Philadelphus lewisii Pursh.		Mock orange; Syringia
Syringa vulgaris		Lilac
ROSACEAE	Rose Family	
Amelanchier alnifolia Nutt.		Serviceberry
Geum macrophyllum Willd.		Large-leaved avens
Potentilla biennis Greene		Biennial cinquefoil
Prunus virginiana var. melanocarpum		Western chokecherry
Prunus virginiana L.		Chokecherry; Plum
Purshia tridentata (Pursh.) DC		Bitterbrush
Rosa woodsii Lindl.		Wood's rose
LEGUMINOSAE	Pea Family	
Astragalus leibergii Jones		Leiberg's milkvetch
Astragalus purshii Dougl. ex. Hook		Woolly-pod milkvetch
Astragalus sclerocarpus Gray		Stalked-pod milkvetch
Astragalus spp.		
Lupinus laxiflorus Dougl. ex Lindl.		
Lupinus laxiflorus Dougl. ex Lindl. var. calcaratus C.P. Smith		
Lupinus lepidus var. aridus (Dougl.) Jeps.		Prairie lupine
Lupinus leucophyllus Dougl. ex Lindl.		Velvet lupine
Lupinus sulphureus Dougl. ex Hook.		Sulphur lupine
Medicago lupulina L.		Medic
Melilotus alba Desr.		Sweet clover
Petalostemon ornatum Dougl. ex Hook.		Prairie clover
Psoralea lanceolata Pursh.		Scruf pea
Robinia pseudo-acacia L.		Black locust
Swainsona salsula (Pall.) Taub. in Engl. & Prantl.		
Vicia americana Muhl. ex Willd.		American vetch
GERIANIACEAE	Geranium Family	
Erodium cicutarium (L.) L'Her. ex Ait.		Hemlock filaree; Stork's bill
ANACARDIACEAE	Sumac Family	
Rhus glalira L.		Sumac
Rhus radicans		Poison ivy
MALVACEAE	Mallow Family	
Sphaeralcea munroana (Dougl.) Spach		Munro's globe mallow
LOASACEAE	Blazing Star Family	
Mentzelia albicaulis Dougl. ex Hook.		Stick leave
Mentzelia laevicaulis (Dougl.) T. & G.		Blazing star
CACTACEAE	Cactus Family	
Opuntia polyacantha Haw.		Prickly pear cactus
ONAGRACEAE	Evening Primrose Family	
Epilobium glaberrimum Barbey in Brew. & Wats.		Smooth willow herb
Epilobium paniculatum Nutt. ex T. & G.		Tall annual willow herb
Epilobium paniculatum Nutt. ex T. & G.		
Oenothera andina Nutt. In T. & G. var. hilgardii (Greene)		Obscure evening primrose
Oenothera boothii		
Oenothera contorta (Dougl.) Kearney		Contorted-pod evening primrose
Oenothera pallida Lindl.		White evening primrose
UMBELLIFERAE	Parsley Family	
Cymopterus terebinthinus Hook. T. & G.		Turpentine cymopterus
Lomatium canbyi Coult. & Rose		
Lomatium dissectum var. multifidum (Nutt.) Math & Const.		Carrot leaf
Lomatium farinosum (Howell) Coult. & Rose		Coeur d'Alene lomatium
Lomatium grayia Coult. & Rose		
Lomatium macrocarpum (Nutt.) Coult. & Rose		Large-flowered desert parsley
Lomatium macrocarpum (Nutt.) Coult. & Rose		
Lomatium triternatum (Pursh.) Coult. & Rose		Desert parsley
CORNACEAE	Dogwood Family	
Cornus stolonifera Michx.		Red-osier dogwood
PRIMULACEAE	Primrose Family	
Dodecatheon conjugens Greene		Shooting star
GENTIANACEAE	Gentian Family	
Centaurium exaltatum (Grieseb) Wight ex Piper		Centaury
APOCYNACEAE	Dogbane Family	
Apocynum sibiricum Jacq.		Dogbane

POLEMONIACEAE	Phlox Family	
Collomia grandiflora Dougl. ex Lindl.		Large flowered collomia
Collomia linearis Nutt.		Narrow-leaved collomia
Gilia minutiflora Benth.		Small flowered gilia
Gilia sinuata Dougl. ex Benth.		Shy gilia
Leptodactylon pungens (Torr.) Nutt.		Shrubby phlox
Linanthus pharnacoides (Benth.) Greene		Thread stem linanthus
Microsteris gracilis (Hook.) Greene		Pink microsteris
Phlox hoodii Rich.		Wild sweet william
Phlox longifolia Nutt.		Long leaf phlox
Polemonium micranthum Benth.		Littlebell's polemonium
HYDROPHYLLACEAE	Waterleaf Family	
Phacelia ciliata		
Phacelia hastata Dougl. ex Lehm		White leaf phacelia
Phacelia linearis (Pursh.) Holz.		Narrow leaved
Phacelia ramosissima Dougl. ex Lehm.		Branched phacelia
BORAGINACEAE	Borage Family	
Amsinckia tessellata Gray		Fiddleneck tarweed
Cryptantha circumscissa (H. & A. Jonst.)		Matted cryptantha
Cryptantha pterocarya (Torr.) Greene		Wing nut cryptantha
Cryptantha sp.		
Hackelia diffusa var. cottonii (Lehm.) Johnst.		Stickseed; Wild forget-me-not
Lappula Sp.		
Lithospermum ruderale Dougl. ex Lehm		Lemonweed
Mertensia oblongifolia (Nutt.) G. Don		Leafy bluebell
Mertensia longiflora Greene		Long-flowered bluebell
VERBENACEAE	Vervain Family	
Verbena bracteata Lag. & Rodr.		Bracted verbena
LABIATAE	Mint Family	
Agastache occidentalis (Piper) Heller		Nettleleaf horsemint
Marrubium vulgare L.		Horehound
Mentha spicata L.		Spearmint
Monardella odoratissima Benth.		Coyote mint
Salvia dorrii (Kell.) Abrams		Purple sage; ballsage
SOLANACEAE	Potato - Nightshade Family	
Solanum triflorum Nutt.		Cut-leafed nightshade
SCROPHULARIACEAE	Figwort Family	
Castilleja thompsonii Pennell		Thompson's Indian paintbrush
Collinsia parviflora Lindl.		Blue-eyed Marry
Collinsia sparsiflora Fisch. & Mey.		Few-flowered blue-eye Mary
Mimulus floribundus Lindl.		Purple-stem monkey flower
Minulus Guttatus DC		Yellow monkey flower
Penstamon acuminatus Dougl. ex Lindl.		Sharp leaved penstamon
Penstamon gairdneri Hook		Gairdner's penstamon
Penstamon glandulosus Dougl. ex Lind.		Sticky stem penstamon
Penstamon eriantherus		Fuzzy-tongue penstamon
Penstamon richardsonii Dougl. ex Lind.		Richardson's p.
Penstamon speciosus Dougl. ex Lind.		Royal p; Showy p.
Verbascum thapsus L.		Common mullein
Veronica americana Schwein.		American water speedwell
OROBANCHACEAE	Broom Rape Family	
Orobanche grayana Beck.		Broom rape
PLANTAGINACEAE	Plantain Family	
Plantago patagonica Jacq.		Indian wheat
RUBIACEAE	Madder Family	
Galium aparine L.		Bedstraw
Galium multiflorum Kell.		Shrubby bedstraw
CAPRIFOLIACEAE	Honeysuckle Family	
Sambucus cerulea Rof.		Elderberry
Symphoricarpos albus (L.) Blake		Snowberry
VALERIANACEAE	Valerian Family	
Plectritis macrocera T. & G.		Corn salad
COMPOSITAE	Composite Family	
Achillea millefolium L.		Yarrow
Agoseris sp.		False dandelio
Antennaria dimorpha (Nutt.) T. & G.		Low pussytoes

Composite Family (Continued)

Arctium minus (Hill) Bernh.	Burdock
Artemisia dracunculus L.	Tarragon; Dragon sagewort
Artemisia tridentata Nutt.	Sagebrush
Artemisia tripartita Rydb.	Three-tip sagebrush
Aster canascens (Pursh.) Gray (Machaeranthera)	Hoary aster
Balsamorhiza careyana Gray	Balsamroot
Balsamorhiza rosea Nels. & Macbr.	Pink balsamroot
Centurea repens. L	Russian knapweed
Chaenactis douglasii (Hook.) H. & S.	Hoary false yarrow
Chrysothamnus nauseosus (Pall.)	Rabbit brush
Chrysothamnus visidiflorus (Hook.)	Green rabbit brush
Cichorium intybus L.	Chicory
Cirsium arvense (L.) Scop.	Thistle
Cirsium vulgare (Savi.) Airy-Shaw	Common thistle; Spear thistle
Conyza canadensis (L.) Cronq.	Horseweed
Crepis atrabarba Heller	Hawk's beard
Crepis barbigera Leib.	Slender hawk's beard
Crepis modocensis Greene	Low hawk's beard
Erigeron corymbosus Nutt.	Foothill daisy
Erigeron filifolius Nutt.	Thread-leaf fleabane
Erigeron linearis (Hook.) Piper	Line-leaf fleabane
Erigeron piperianus Cronq.	Piper's daisy
Erigeron poliospermus Gray	Howell's erigeron
Eriophyllum lanatum (Pursh.)	
Ambrosia acanthicarpa (Hook.) Colville	Sandburr
Gnaphalium chilense Spreng.	Cudweed; Everlasting
Haplopappus stenophyllus Gray	Narrow-leaved golden weed
Helianthella uniflora Nutt. T. & G.	
Hymenopappus filifolius Hook.	
Iva xanthifolia Nutt.	Poverty weed; Marshelder
Lactuca serriola L.	Prickly lettuce
Layia glandulosa	White daisy tidy-tips
Madia exigua (J.E. Smith) Gray	Tarweed
Microseris troximoides Gray	False agoseris
Senicio hydrophilus Nutt.	Alkali march butterweed
Solidago occidentalis (Nutt.) T. & G.	Western goldenrod
Sonchus asper (L.) Hill.	Sow thistle
Stephanomeria tenuifolia (Torr.) Hall	Rush pink; Skeletonweed
Stephanomeria paniculata Nutt.	Stiff-branched wire lettuce
Taraxacum officinale Weber in Wiggens	Dandelion
Tetradymia canascens DC	Horsebrush
Townsendia florifer (Hook.) Gray	Daisy
Xanthium strumarium L.	Cockleburr

APPENDIX II.3-G, PART 3

Vertebrate Taxa of the Hanford Reservation

AMPHIBIANS[1]

Pelobatidae	Toads and Frogs
Scaphiopus intermountanus	Great Basin Spadefoot
Bufonidae	
Bufo boreas	Western toad
Hylidae	
Hyla regilla	Pacific Treefrog
Ranidae	
Rana pretiosa	Spotted Frog
R. pipiens	Leopard Frog
R. catesbeiana	Bullfrog
Testunidae	Turtles
Chrysemys picta	Painted turtle

REPTILES[1]

Iguanidae	Lizards
Sceloporus graciosus	Sagebrush lizard
Uta stansburiana	Side-blotched lizard
Phrynosoma douglassi	Short-horned lizard
Colubridae	Snakes
Masticophis taeniatus	Striped whipsnake
Coluber constrictor	Western yellow-bellied racer
Pituophis melanoleucos	Gopher snake
Thamnophis elegans	Garter snake
Hyspiglena torquata	Desert night snake
Viperidae	
Crotalus viridis	Pacific rattlesnake

BIRDS[2,3]

Podicipidae	
Podiceps auritus	Horned Grebe
Podiceps caspicus	Eared Grebe
Aechomphorus occidentalis	Western Grebe
Podilymbus podiceps	Pied-billed Grebe
Pelicanidae	
Pelecanus erythrorhynchos	White Pelican
Ardeidae	
Ardea herodias	Great Blue Heron
Nycticorax nycticorax	Black-crowned Night Heron
Botaurus lentiginosus	American Bittern
Anatidae	
Olor columbianus	Whistling Swan
Branta canadensis	Canada Goose
Anas platyrhynchos	Mallard
Anas strepera	Gadwall
Anas acuta	Pintail
Anas crecca cardinensis	Green-winged Teal
Anas discors	Blue-winged Teal
Anas cyanoptera	Cinnamon Teal
Anas americana	American Wigeon
Anas clypeata	Shoveler
Aythya americana	Redhead Duck
Aythya collaris	Ring-necked Duck
Aythya valisneria	Canvasback
Aythya affinis	Lesser Scaup
Bucephala clangula	Common Goldeneye
Bucephala islandica	Barrows Goldeneye
Bucephala albeola	Bufflehead
Clangula hyemalis	Oldsquaw
Oxyura jamaicensis	Ruddy Duck

BIRDS (Continued)

Merginae	
Lophodytes cucullatus	Hooded Merganser
Mergus merganser	Common Merganser
Accipitridae	
Buteo jamaicensis	Red-tailed Hawk
Buteo swainsoni	Swainson's Hawk
Buteo lagopus	Rough-legged Hawk
Buteo regalis	Ferruginous Hawk
Aquila chrysaetos	Golden Eagle
Haliacetus leucocephalis	Bald Eagle
Circus cyaneus	Marsh Hawk
Pandionidae	
Pandion haliaetus	Osprey
Falconidae	
Falco mexicanus	Prairie Falcon
Falco sparverius	Sparrow Hawk
Tetraonidae	
Pedioecetes phasianellus	Sharp-tailed Grouse
Centrocereus urophasianus	Sage Grouse
Phasianidae	
Lophortyx californicus	California Quail
Phasianus colchicus	Ring-necked Pheasant
Alectoris chukar	Chuckar Partridge
Perdix perdix	Gray (Hungarian) Partridge
Rallidae	
Fulica americana	American Coot
Charadriidae	
Charadrius vociferus	Killdeer
Scalopacidae	
Capella gallinago	Common Snipe
Numerius americanus	Long-billed Curlew
Actitis macularia	Spotted Sandpiper

BIRDS (Continued)

Tringa melanoleucus	Greater Yellowlegs
Tringa flavipes	Lesser Yellowlegs
Calidris alpina	Dunlin
Calidris mauri	Western Sandpiper
Limnodromus griseus	Long-billed Dowitcher
Recurvirostridae	
Recurvirostra americana	American Avocet
Phalaropididae	
Steganopus tricolor	Wilson Phalarope
Lobipes lobatus	Northern Phalarope
Laridae	
Larus californicus	California Gull
Larus delawarensis	Ring-billed Gull
Columbidae	
Zenaida macroura	Mourning Dove
Columbia livia	Rock Dove
Tytonidae	
Tyto alba	Barn Owl
Strigidae	
Bubo virginianus	Great Horned Owl
Speotyto cunicularia	Burrowing Owl
Asio otus	Longeared Owl
Caprimulgidae	
Chordeiles minor	Common Nighthawk
Alcedinidae	
Megaceryle alcyon	Belted Kingfisher
Picidae	
Colaptes auratus cafer	Red-shafted Flicker
Dendrocopos pubescens	Downy Woodpecker
Tyrannidae	
Tyrannus tyrannus	Eastern Kingbird
Tyrannus verticalis	Western Kingbird

BIRDS (Continued)

Myiarchus cinerascens	Ash-throated Flycatcher
Sayornis saya	Say's Phoebe
Alaudidae	
Eremophila alpestris	Horned Lark
Hirundinidae	
Hirundo rustica	Barn Swallow
Petrochelidon pyrrhonota	Cliff Swallow
Corvidae	
Pica pica	Black-billed Magpie
Corvus corax	Common Raven
Corvus brachyrhynchos	Common Crow
Nucifraga columbiana	Clark's Nutcraker
Sittidae	
Sitta canadensis	Red-breasted Nuthatch
Troglodytidae	
Troglodytes troglodytes	Winter Wren
Telmatodytes palustris	Long-billed Marsh Wren
Catherpes mexicanus	Canyon Wren
Salpinctes obsoletus	Rock Wren
Mimidae	
Mimus polyglottos	Mockingbird
Oreoscoptes montanus	Sage Thrasher
Turdidae	
Turdus migratorius	Robin
Ixoreus naevius	Varied Thrush
Catharus guttata	Hermit Thrush
Myadestes townsendi	Townsend's Solitaire
Sylviidae	
Regulus satrapa	Golden-crowned Kinglet
Regulus calendula	Ruby-crowned Kinglet
Motacillidae	
Anthus spinoletta	Water Pipit

BIRDS (Continued)

Bombycillidae	
Bombycilla cedrorum	Cedar Waxwing
Laniidae	
Lanius ludovicianus	Loggerhead Shrike
Sturnidae	
Sturnus vulgaris	Starling
Virionidae	
Vireo huttoni	Hutton's Vireo
Vireoolivaceus	Red-eyed Vireo
Vireo gilvus	Warbling Vireo
Parulidae	
Vermivora celata	Orange-crowned Warbler
Vermivora ruficapilla	Nashville Warbler
Dendroica petechia	Yellow Warbler
Dendroica coronata coronata	Myrtle Warbler
Dendroica coronata auduboni	Audubon's Warbler
Dendroica townsendi	Townsend's Warbler
Wilsonia pusilla	Wilson's Warbler
Ploceidae	
Passer domesticus	House Sparrow
Icteridae	
Sturnella neglecta	Western Meadowlark
Xanthocephalus xanthocephalus	Yellow-headed Blackbird
Agelaius phoeniceus	Red-winged Blackbird
Icterus galbula bullockii	Bullock's Oriole
Euphagus cyanocephalus	Brewer's Blackbird
Molothrus ater	Brown-headed Cowbird
Thraupidae	
Prianga ludoviciana	Western Tanager
Fringillidae	
Passerina amoena	Lazuli Bunting
Carpodacus mexicanus	House Finch

BIRDS (Continued)

Spinus tristis	American Goldfinch
Pipilo erythrophthalmus	Rufous-sided Towhee
Ammodramus savannarum	Grasshopper Sparrow
Pooecetes gramineus	Vesper Sparrow
Chondestes grammacus	Lark Sparrow
Amphispiza belli	Sage Sparrow
Junco hyemalis	Junco
Spizella breweri	Brewer's Sparrow
Zonotrichia leucophrys	White-crowned Sparrow
Zonotrichia atricapilla	Golden-crowned Sparrow

MAMMALS*

Insectivora (Insect-eaters)	
Sorex merriami	Merriam Shrew
Chiroptera (Bats)(a)	
Myotis lucifugus	Little Brown Bat
Lasionycteris noctivagans	Silver-haired Bat
Lasiurus cinereus	Hoary Bat
Carnivora (Flesh-eaters)	
Procyon lotor	Raccoon
Mustela vison	Mink
Mustela frenata	Long tailed Weasel
Taxidea taxis	Badger
Mephitis mephitis	Striped Skunk
Canis latrans	Coyote
Lynx rufus	Bobcat
Rodentia (Gnawing Mammals)	
Eutamias minimus	Least Chipmunk
Citellus townsendii	Townsend's Ground Squirrel
Thomomys talpoides	Northern Pocket Gopher
Perognathus parvus	Great Basin Pocket Mouse

MAMMALS (Continued)

Castor canadensis	Beaver
Reithrodontomys megalotis	Western Harvester Mouse
Peromyscus maniculatus	Deer Mouse
Onychomys leucogaster	Northern Grasshopper Mouse
Neotoma cinerea	Bushytail Woodrat
Microtus montanus	Mountain Vole
Lagurus curtatus	Sagebrush Vole
Ondatra zibethicus	Muskrat
Mus musculus	House Mouse
Rattus norvegicus	Norway Rat
Erethizon dorsatum	Porcupine
Lagomorpha (Hares and Rabbits	
Lepus californicus	Black-tailed Jack Rabbit
Sylvilagus nuttallii	Nuttall Cottontail Rabbit
Artiodactyla (Even-toed Hoofed Mammals)	
Odocoileus hemionus	Mule Deer
Odocoileus virginianus	Whitetailed Deer(b)
Cervus canadensis	Elk(c)

(a) Most bats are occasional visitors only.
(b) Resident but very low in number.
(c) Accidental.

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APPENDIX II.3-G, Part 4

Insects of the Hanford Reservation

COLEOPTERA[a]

Anthicidae

Notoxus sp.

Buprestidae

Agrilus politus (Say)

Chrysobothris sp.

Carbidae

Agonum jejunum LeC.

Amara sp.

Calosoma luxatum Say

Carabus taedutus F.

Cymindis brevipennis Zimmerman

Harpalus sp.

Chrysomelidae

Disonycha alternata Illiger

Glyptoscelis artemisiae Blake

Monoxia grisea Blake

Pachybrachis abdominalis Say

Phyllotreta sp.

Cicindelidae

Cicindela oregona LeC.

Cicindela purpurea Ol.

Omus californicus Reiche

(a) Only those groups identified to at least generic level are included. Many important invertebrate families are awaiting specific determinations and were excluded from this list.

COLEOPTERA (continued)

Cleridae

Enoclerus eximius Mann.

Phyllobaenus sp.

Coccinellidae

Coccinella novemnotata Herbst

Hippodamia convergens Guerin

Hyperaspis elliptica Casey

Hyperaspis fastidiosa Casey

Hyperaspis quadrivittata LeC.

Hyperaspidius vittigera LeC.

Scymnus intrusoides Hatch

Scymnus (Pullus) sp.

Curculionidae

Anthonomus sp.

Baris sp.

Cercopedius artemisiae Pierce

Cleonus trivittatus Say

Dyslobus alternatus Horn

Ophryastes cinerascens Pierce

Sitona californicus Fahr.

Stamoderes lanei Van Dyke

Tychius lineelus LeC.

Dermestidae

Dermestes caninus Germar

Histeridae

Saprinus sp.

Saprinus copei Horn

COLEOPTERA (continued)

Meloidae

Epicauta oregona Horn

Epicauta normalis Werner

Epicauta puncticollis Mann.

Lytta vulnerata cooperi LeC.

Zonitis vermiculatis schaeffer

Melyridae

Anthocomus antennatus Hopping

Anthocomus horni Fall

Collops hirtellus LeC.

Collops versatilis Fall

Mordellidae

Mordellistena aspersa Melsh.

Scarabaeidae

Aphodius distinctus Muller

Aphodius fossor L.

Aphodius granarius L.

Aphodius haemorrhoidalis L.

Aphodius hirsutus Brown

Aphodius washtucna Robinson

Coenonycha sp.

Cremastocheilus pugetanus Csy.

Diplotaxis subangulata LeC.

Diplotaxis tenebrosa Fall

Glaresis clypeata Van Dyke

Onthophagus nuchicornis L.

Paracotalpa granicollis Haldeman

Pleurophorus caesus Creutzer

COLEOPTERA (continued)

Silphidae

Necrophorus marginatus F.

Tenebrionidae

Blapstinus discolor Horn

Blapstinus substriatus Champion

Coniontis lanei Boddy

Coniontis ovalis Ulke

Coniontis setosa Casey

Conisattus nelsoni Boddy

Eleodes granulata LeC.

Eleodes hispilabris imitabilis Blais.

Eleodes humeralis LeC.

Eleodes nigrina difformis Blais.

Eleodes novoverrucula Boddy

Eleodes obscura Say

Eusattus muricatus LeC.

Oxygonodera hispidula Horn

Philolithus densicollis Horn

Stenomorpha puncticollis LeC.

COLLEMBOLA

Isotomidae

Isotoma viridis Bourlet

Sminthuridae

Bourletiella hortensis Fitch

DIPTERA

Acroceridae

Eulonchus n. sp.

Anthomyiidae

Hylemya cinerella Fallen

Hylemya neomexicana Malloch

Scatophaga furcata Say

Scatophaga stercoraria L.

Apioceridae

Apiocera sp.

Asilidae

Ablautus colei Wilcox

Cyrtopogon sp.

Cyrtopogon ablautoides Melander

Dioctria sp.

Efferia albibarbis Macquart

Efferia benedicti Bromley

Efferia coulei Wilcox

Efferia harveyi Hine

Lasiopogon chaetosus Cole and Wilcox

Leptogaster sp.

Lestomyia n. sp.

Myelaphus sp.

Nicocles utahensis Banks

Proctacanthus sp.

Promachus sp.

Scleropogon neglectus Bromley

DIPTERA (continued)

Asilidae (continued)

Stenopogon inquinatus Loew

Stenopogon martini Bromley

Tolmerus sp.

Bombyliidae

Conophorus obesulus Loew

Villa sp.

Calliphoridae

Calliphora vicina R.-D.

Phormia regina Meigen

Cecidomyiidae

Lestremia sp.

Ceratopogonidae

Culicoides crepuscularis Mall.

Chironomidae

Cricotopus sp.

Tanytarsus sp.

Chloropidae

Hippelates pusio Loew

Meromyza nigriventris Macquart

Oscinella carbonaria Lw.

Thaumatomyia appropinqua Ad.

Thaumatomyia glabra Mg.

Ephydridae

Hydrellia griseola Fallen

Philygria debilis Lw.

Scatella stagnalis Fallen

DIPTERA (continued)

Milichiidae

- *Leptometopa halteralis* Coq.

Muscidae

- *Fannia* sp.
- *Musca domestica* L.
- *Schoenomyza dorsalis* Loew

Mycetophilidae

- *Docosia* sp.

Nemestrinidae

- *Neorhyncocephalus sackenii* Williston

Otitidae

- *Ceroxys latiusculus* Loew
- *Physiphora demandata* F.

Sarcophagidae

- *Blaesoxipha falciformis* Aldrich
- *Helicobia rapax* Walker
- *Ravinia lherminieri* R.D.
- *Sarcophaga* sp.
- *Senotainia* sp.
- *Taxigramma heteroneura* Meigen

Scenopinidae

- *Brevitrichia* sp.
- *Scenopinus whittakeri* James

Sciaridae

- *Bradysia* sp.

DIPTERA (continued)

Sepsidae

- *Sepsis neocynipsea* Melander and Spuler

Stratiomyidae

- *Nemotelus* sp.

Syrphidae

- *Eristalis tenax* L.
- *Metasyrphus meadii* Jones
- *Scaeva pyrastri* L.
- *Syrphus opinator* Osten Sacken
- *Syrphus torrus* Osten Sacken

Tachinidae

- *Acemya* sp.
- *Alophorella* sp.
- *Catagoniopsis* sp.
- *Euphorocera* sp.
- *Exorista mella* Wlk.
- *Gonia frontosa* Say.
- *Ostracophyto aristalis* Tns.
- *Peleteria* sp.
- *Periscepsia cinerosa* Coq.
- *Periscepsia helymus* Wlk.
- *Procatharosia calva* Coq.
- *Stomatomyia parvipalpis* Wulp
- *Uclesia retracta* Ald.

Tephritidae

- *Euaresta tapetis* coquillett
- *Oxyna utahensis* Quisenberry

DIPTERA (continued)

Therevidae

- *Psilocephala baccata* Coquillett
- *Thereva* sp.

Tipulidae

- *Tipula* (*Lunatipula*) *dorsimacula* Walker

Trixoscelididae

- *Trixoscelis* sp.

HEMIPTERA

Coreidae

- *Leptoglossus occidentalis* Heidemann

Lygaeidae

- *Neosuris castanea* Barber

Miridae

- *Stenodema vicinum* Prov.

Reduviidae

- *Zelus* sp.

Saldidae

- *Saldula* sp.

HOMOPTERA

Cicadellidae

- *Aceratagallia* sp.
- *Ballana* sp.
- *Carsonus aridus* Ball
- *Circulifer tenellus* Baker

HOMOPTERA (continued)

Cicadellidae (continued)

- Collandonus germinatus Van Duzee
- Commellus sexvittatus Van Duzee
- Dikraneura carneola Stal.
- Empoasca neaspera Oman and Wheeler
- Empoasca nigra Gillette and Baker
- Errhomus n. sp.
- Psammotettix sp.
- Sorhoanus debilis Uhler
- Texananus extremus Ball
- Xerophloea peltata Uhler

Cicadidae

- Okanagana utahensis Davis

Ortheziidae

- Orthezia sp.

Pseudococcidae

- Trionymus winnemucae McKenzie

HYMENOPTERA

Aphidiidae

- Lysiphlebus sp.

Argidae

- Schizocerella pilicornis Holmgren

Braconidae

- Agathis sp.
- Apanteles sp.
- Bracon gelechiae Ashm.

HYMENOPTERA (continued)

Braconidae (continued)

- Cremnops californicus Morr.
- Microctonus sp.
- Microplitis sp.
- Orgilus strigosus Mues.

Bethylidae

- Epyris cochise Evans

Ceraphronidae

- Ceraphron sp.

Chrysididae

- Ceratochrysis sp.
- Chrysis sp.
- Chrysura sp.

Encyrtidae

- Copidosoma sp.

Eulophidae

- Euderus sp.
- Tetrastichus coerulescens Ashmead

Eumenidae

- Pterocheilus decorus Cresson
- Pterocheilus provancheri Huard
- Stenodynerus sp.

Eurytomidae

- Bruchophagus sp.
- Harmolita sp.

HYMENOPTERA (continued)

Formicidae

- Camponotus semitestaceus Emery
- Camponotus vicinus Mayr
- Formica manni Wheeler
- Formica neogagates Emery
- Formica subpolita camponoticeps Wheeler
- Lasius crypticus Wilson
- Lasius sitkaensis Pergande
- Monomorium pharaonis L.
- Myrmecocystus testaceus Emery
- Pheidole californica oregonica Emery
- Pheidole creightoni Gregg
- Pogonomyrmex owyheei Cole
- Solenopsis molesta validiuscula Emery
- Tapinoma sessile Say

Ichneumonidae

- Anomalon sp.
- Campoletis sp.
- Diphyus sp.
- Diolazon laetatorius F.
- Erigorgus sp.
- Euryproctus sp.
- Lissonota sp.
- Meringopus dirus Prov
- Ophion sp.
- Pterocormus sp.
- Temelucha sp.

HYMENOPTERA (continued)

Mutillidae

Odontophotopsis sp.

Sphaeropthalma (*Photopsis*) sp.

Pompilidae

Aporinellus sp.

Episyron snowi Vierock

Pompilus (*Ammosphex*) sp.

Priocnemis oregona Banks

Tachypompilus torridus unicolor Banks

Pteromalidae

Gastrancistrus aphidis Girault

Mesopolobus sp.

Scelionidae

Gryon sp.

Sphecidae

Ammophila aberti Haldeman

Ammophila azteca Cameron

Ammophila karenae Menke

Ammophila mcclayi Menki

Cerceris sp.

Pidalonia mexicana Saussure

Podalonia luctuosa Smith

Podalonia valida Cresson

Prionyx atratus Lepeletier

Sphecius grandis Say

Stictiella emarginata Cresson

Stizoides unicinctus Say

HYMENOPTERA (continued)

Sphecidae (continued)

Tachysphex sp.

Tachytes californicus Bohart

Tachytes distinctus Smith

Tiphiidae

Brachycistis sp.

Vespidae

Polistes fuscatus F.

Vespula pensylvanica Saussure

ISOPTERA

Rhinotermitidae

Reticulitermes hesperus Banks

LEPIDOPTERA

Arctiidae

Apantesis sp.

Coleophoridae

Coleophora sp.

Gelechiidae

Aroga rigidae Clarke

Chionodes sp.

Noctuidae

Euxoa sp.

Feltia ducens Walker

Feltia Herilis Grote

Feltia subgothica Haworth

LEPIDOPTERA (continued)

Noctuidae (continued)

Lacinipolia pensilis Grote

Nephelodes emmedonia Cramer

Rhynchagrotis sp.

Schinia sp.

Spaelotis clandestina Harris

Ufeus hulsti J. B. Smith

Pyralidae

Crambus attenuatus Grote

Crambus whitemerellus Klots

Saturniidae

Hemileuca hera Harris

Scythridae

Scythris sp.

Tischeriidae

Coptotriche sp.

NEUROPTERA

Arctiidae

Apantesis sp.

Chrysopidae

Chrysopa coloradensis Bks.

Chrysopa excepta Bks.

Eremochrysa tibialis Bks.

Myrmeleontidae

Paranthaclisis congener Hag.

NEUROPTERA (continued)

Raphidiidae

Agulla bicolor Alb.

ORTHOPTERA

Acrididae

Ageneotettix deorum Thomas

Amphitornus coloradus Thomas

Arphia pseudonietana Thomas

Aulocara elliotti Thomas

Circotettix undulatus Thomas

Conozoa wallula Scudder

Cratypedes neglectus Thomas

Dissosteira carolina L.

Melanoplus bivittatus Say

Melanoplus cinereus cinereus Scudder

Melanoplus sanguinipes sanguinipes F.

Oedaleonotus enigma Scudd.

Paropomala pallida Bruner

Psoloessa delicatula buckelli Rehn

Trimerotropis caeruleipennis Bruner

Trimerotropis fontana Thomas

Trimerotropis gracilis sordida Walker

Trimerotropis pallidipennis pallidipennis Burmeister

Trimerotropis sparsa Thomas

Xanthippus lateritius Sauss.

Gryllacrididae

Ceuthophilus vicinus Hubbell

ORHTOPTERA (continued)

Gryllidae

Gryllus sp.

Oecanthus argentinus Sauss.

Oecanthus quadripunctatus Beutenmuller

Mantidae

Litaneutria minor Scudd.

Tettigoniidae

Steiroxys sp.

PSOCOPTERA

Liposcelidae

Liposcelis sp.

TRICHOPTERA

Hydroptilidae

Hydroptila xera Ross

Hyrodpsychidae

Cheumatopsyche campyla Ross

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APPENDIX II.3-G, Part 5

Shrub-Steppe Biota on the Hanford Reservation

Summary of the distribution of important shrub-steppe biota on the Hanford Reservation in relation to elevation and vegetation associations.

Decreasing elevation →

Thyme Eriogonum	Sagebrush/ Bluebunch Wheatgrass	Sagebrush/ Sandberg Bluegrass	Winter Fat	Greasewood	Sagebrush- Bitterbrush	Sand Dune	Plant associations
							Plant taxa
X							Eriogonum thymoides
X							Haplopappus stenophyllus
X							Balsamorhiza rosea
X							Phlox hoodii
X	X	X	X	X	X		Poa secunda
	X						Agropyron spicatum
	X						Stipa thurberiana
	X	X	X		X		Phlox longifolia
	X	X	X				Erigeron filifolius
	X	X	X		X		Artemisia tridentata
	X	X					Crepis atrabarba
	X	X	X		X		Calochortus macrocarpus
			X				Eurotia lanata
				X			Sacrobatus vermiculatus
				X			Distichlis stricta
					X		Purshia tridentata
					X	X	Rumex venosus
						X	Oenothera pallida
						X	Psoralea lanceolata
						X	Agropyron dasystachyum
						X	Coriospermum hyssopifolium
						X	Oryzopsis hymenoides
							Birds
X	X	X	X	X	X		Horned Lark
	X	X	X	X	X		Meadowlark
	X	X	X	X	X		Mourning Dove
	X	X	X				Sage Sparrow
	X	X	X	X	X		Loggerhead Shrike
							Mammals
X	X	X	X	X	X		Deer Mouse
X	X	X	X	X	X		Pocket Mouse
X	X	X	X	X	X		Grasshopper Mouse
		X	X	X	X		Jackrabbit
	X	X					Sagebrush Vole
X	X	X	X	X	X		Coyote
X	X	X	X	X	X		Mule Deer
							Reptiles
	X	X	X	X	X		Sideblotched Lizard
X	X	X	X	X	X		Horned Lizard
X	X	X	X	X	X		Gopher Snake
X	X	X	X	X	X		Rattlesnake
							Insects
X	X	X	X	X	X		Philolithus densicollis
X	X	X	X	X			Stenomorpha puncticollis
X	X	X	X	X	X		Eleodes hispilabris
X	X	X	X	X	X		Melanopus sanguinipes

APPENDIX III-A

MODELS AND COMPUTER CODES FOR EVALUATING ENVIRONMENTAL RADIATION DOSES

APPENDIX III-A

MODELS AND COMPUTER CODES FOR EVALUATING ENVIRONMENTAL RADIATION DOSES

APPENDIX III-A, Part 1

<u>Programs ARRRG, CRITR and GRONK</u>

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III-A, Part 1 Programs ARRRG, CRITR and GRONK

III-A.1 Introduction

The methods used for computing environmental radiation doses and for evaluating radiological impact are presented in detail in this appendix.[21]

To meet current needs, a simplified model for calculation of radiation doses from radioactive effluents was developed and programmed into a conversational language, providing the fast turn-around time required. The new model is divided into four independent parts, each written as a separate program:

- ARRRG: calculates individual and population doses from liquid effluents
- CRITR: calculates internal radiation doses to four common classes of aquatic organisms and to organisms which consume them
- GRONK: calculates doses from gaseous effluents, to individuals and to the total population within 50 miles
- FOOD: calculates doses from consumption of food crops and animal products produced on irrigated farms

The model can be used to calculate radiation doses to the whole body and selected organs of individuals and population groups, and to organisms other than man. Included are all air and liquid exposure pathways thought to be significant and for which a reasonable amount of supporting data is available. Internal doses to man are based on a 1-year radionuclide intake, assuming no prior accumulation in the body. The radionuclide content of ingested food is assumed to be at equilibrium with the environment.

Part 1 of this appendix discusses the models in detail and describes the programs ARRRG, CRITR, and GRONK. FOOD is described in Part 2. The question-and-answer format of these programs allows them to be used by nonprogrammers. Although the programs were originally intended specifically for nuclear reactors, they are applicable to any nuclear facility which releases radioactive effluents to air or water.

III-A.2 Pathways of Exposure

The pathways of consequence by which man can be exposed to radiation from a nuclear facility can be grouped into those associated with gaseous effluents, those associated with liquid effluents, and those involving exposure to direct radiation from the facility or from transportation of radioactive materials to or from the facility. The exposure pathways are arranged by group in Table III-A-1. Calculations for each pathway are made for those selected organs which could potentially receive the highest radiation dose.*

The pathways of consequence by which organisms other than man can be exposed to radiation from a nuclear facility are similar to those for man. Table III-A-2 is a more inclusive list of pathways of exposure to organisms other than man.

In this appendix, aquatic organisms are designated as "primary" organisms if a bioaccumulation factor for them was found in the literature. The bioaccumulation factor relates equilibrium concentration of a radionuclide in the organism to that in its water environment, including contributions from direct assimilation of nuclides from water and ingestion of food and water. "Secondary" aquatic and terrestrial organisms are those that feed upon primary organisms; their dose must be calculated from their diet.

III-A.3 Dose to Man--Basic Considerations

The fundamental equation for calculation of radiation dose from the pathways described above is

$$R_{ipr} = C_{ip} U_p D_{ipr} \tag{1}$$

where

R_{ipr} = dose rate to organ r from nuclide i via pathway p

C_{ip} = concentration of nuclide i in the medium of pathway p

U_p = usage: the exposure or intake rate associated with pathway p

---

* Table III-A-10 includes a list of these organs for each pathway.

D_{ipr} = dose factor: a number specific to a given nuclide i, pathway p, and organ r which can be used to calculate radiation dose rate from exposure to a given radionuclide concentration or radionuclide intake

The three terms on the right of Equation 1 are discussed in the following subsections. Equations tailored to each specific exposure pathway are derived from Equation 1. The principal difference between pathways is the manner in which the radionuclide concentrations are calculated.

TABLE III-A-1

PATHWAYS OF EXPOSURE TO MAN

Pathways	Equation	Computer Program
Water Pathways		
External		
Water immersion and water surface	7	ARRRG
Exposure to shoreline	6	ARRRG
Internal		
Ingestion of water	2	ARRRG
Ingestion of aquatic foods	3	ARRRG
Ingestion of irrigated food crops	--	FOOD(a)
Ingestion of products from animals fed irrigated foods	--	FOOD(a)
Air Pathways		
External		
Air submersion	8	GRONK
Exposure to deposited materials(b)	--	--
Internal		
Inhalation	8	GRONK
Transpiration of tritium oxide	8	--
Ingestion of food crops	8	GRONK
Ingestion of animal products	8	GRONK
Direct Radiation Pathways		
External		
Direct radiation from the facility	--	--
Exposure during transport of fuels and solid wastes(b)	(c)	--

(a) The program FOOD is included in Part 2 of this Appendix.
(b) Doses from these pathways are generally insignificant.
(c) Reference 1.

III-A.3.1 Concentrations of Nuclides in Environmental Media, C_{ip}

Concentrations of nuclides in air, water, soil or food are calculated as intermediate steps in the computer programs described in Section III-A.7. Concentrations in water, in aquatic foods, and on shoreline sediment are calculated from the radionuclide release rates, the effluent flow rate, the mixing and dilution in the receiving waters, and bioaccumulation factors for aquatic foods. Concentrations in air and on vegetation from aerial deposition are generated from radionuclide release rates and from the equations for atmospheric dispersion given in Equations 8 and 9.

Concentrations of nuclides in irrigated farm produce are calculated from concentrations of radionuclides in the irrigation water, irrigation rate, facility lifetime (determines long-term soil buildup), and decay time between nuclide release and produce consumption.

III-A.3.2 Usages, U_p

Usage refers to duration of exposure to external sources of radiation and to intake rates of ingested water and food. For pathways other than air submersion, the usage depends on the specific

TABLE III-A-2

PATHWAYS OF EXPOSURE TO ORGANISMS OTHER THAN MAN

Pathway and Organism Type	Equation	Computer Program
Water Pathways		
External		
Water immersion and water surface (Primary, Secondary)[(a)]	7	ARRRG
Exposure to sediment or shoreline (Primary, Secondary)	6	ARRRG
Internal		
Ingestion of water and aquatic foods (Primary)	12	CRITR
Ingestion of water (Secondary)	2	ARRRG
Ingestion of primary aquatic foods (Secondary)	16	CRITR
Air Pathways		
External		
Air submersion (Secondary)	8	GRONK
Exposure to deposited materials (Secondary)[(b)]	--	--
Internal		
Inhalation (Secondary)[(b)]	8	GRONK
Direct Radiation Pathways		
External		
Direct radiation from the facility (Secondary)[(b)]	--	--

(a) Organism types exposed via the given pathway are listed in parentheses.
(b) Doses from these pathways are generally insignificant.

situation. Since noble gases are the principal contributors to air submersion dose, the assumption is made that the air concentrations of radionuclides are essentially the same indoors as outdoors. Thus, no shielding and occupancy factors are applied, and 8766 hr/yr is used for the air submersion pathway.

In the absence of site-specific data, the usages and exposure times in Table III-A-3 are employed to calculate individual adult doses. For population dose calculations the usages of the average adult are multiplied by the size of the population.

III-A.3.3 Dose Factors, D_{ipr}

Equations for calculating internal dose factors were previously published.[2,3] They were derived originally from those given by the International Commission on Radiological Protection[4] (ICRP) for body burden and maximum permissible concentration. For this study, effective decay energies for the radionuclides are calculated from the ICRP model which assumes all of the radionuclide is at the center of a spherical organ with an appropriate effective radius. Where data are lacking, metabolic parameters for the Standard Man are used for other ages as well. Internal dose factors have units of mrem/yr per pCi/yr intake via ingestion or inhalation, and represent the first year's dose from one year's intake. For calculating external dose factors from air submersion or water immersion, the penetrating power of the radiation emitted determines whether it contributes to skin dose only or to both skin and whole body dose. Beta and gamma radiation which can penetrate 7×10^{-3} cm of tissue is considered to contribute to skin dose; that which can penetrate 5 cm of tissue is considered to contribute to whole body dose (and dose to internal organs). The dose factors for air submersion and water immersion are derived by assuming that the contaminated medium is an infinite volume compared to the range of the emitted radiations. Under this assumption, the energy emitted per gram of medium equals the energy absorbed per gram of medium. Corrections must be applied for differences in energy absorption between tissue and air or water,

TABLE III-A-3

RECOMMENDED ADULT VALUES FOR U_p TO BE USED IN LIEU OF SITE-SPECIFIC DATA

Pathway	Maximum Individual Adult	References	Average Adult	References
Air Submersion	8766 hr/yr	(3)	8766 hr/yr	(3)
Inhalation	7300 m^3/yr	(4)	7300 m^3/yr	(4)
Drinking Water	730 liter/yr	(3)	438 liter/yr	(4)
Local Seafood -fish	18 kg/yr		2.3 kg/yr	(5)
-crustacea	9 kg/yr		0.9 kg/yr	(5)
-molluscs	9 kg/yr		0.25 kg/yr	(5)
Local Fresh Water Fish	18 kg/yr		2.2 kg/yr	(5)
Holdup Time for Aquatic Foods	24 hr		24 hr	
Aquatic Recreation:				
Ocean - shoreline activ.	500 hr/yr	(6)	4 hr/yr[(a)]	(3)
- swimming	100 hr/yr	(7)	1 hr/yr[(a)]	(3)
- boating	100 hr/yr	(7)	1 hr/yr[(a)]	(3)
River - shoreline activ.	500 hr/yr	(6)	2 hr/yr[(b)]	(3)
- swimming	100 hr/yr	(7)	4 hr/yr[(b)]	(3)
- boating	100 hr/yr	(7)	4 hr/yr[(b)]	(3)
Lake - shoreline activ.	500 hr/yr	(6)	1 hr/yr[(a)]	(3)
- swimming	100 hr/yr	(7)	2 hr/yr[(a)]	(3)
- boating	100 hr/yr	(7)	4 hr/yr[(a)]	(3)

(a) These are hours spent in the vicinity of the site. Other hours are spent in areas unaffected by the liquid effluent from the facility.
(b) These are hours spent downstream of the site. Other hours are spent upstream and at nearby lakes.

physical geometry of the specific exposure situation and the conversion from MeV per disintegration per gram to rem. The resulting dose factors have units of mrem/hr per pCi/m^3 of air or mrem/hr per pCi/liter of water.

Material deposited from the air or from irrigation water onto the ground represents a fairly large, nearly uniform, thin sheet of contamination. The factors for converting surface contamination in pCi/m^2 to gamma dose at 1 meter above a uniformly contaminated plane are described in the literature.[2,3,8] Dose factors for exposure to soil (or river sediment) have units of mrem/hr per pCi/m^2 of surface.

A set of dose factors for 45 radionuclides was calculated originally for the Year 2000 Model.[3] These are recalculated using the latest available decay schemes[9] for an expanded list of 136 nuclides.*

III-A.4 Dose to Man--Liquid Pathways

III-A.4.1 Drinking Water

The dose rate from ingestion of water is calculated by

$$R_{pr} = 1119 \sum_{i=1}^{136} \frac{Q_i \; N_i}{F} M_p \; e^{-\lambda_i t_p} \; U_p \; D_{ipr} \qquad (2)$$

where

R_{pr} = dose rate to organ r from all of the nuclides i via pathway p (mrem/yr)

* The revised list is given in Table III-A-13. An explanation of the terms "+D" and "D" appearing in this table is given in Section III-A.7.6.

N_i = reconcentration factor as defined in Section III-A.7.5

Q_i = release rate of nuclide i (Ci/yr)

F = flow rate of the liquid effluent (ft^3/sec)

M_p = mixing ratio at the point of exposure (or the point of withdrawal of drinking water or the point of harvest of aquatic food) as defined in Section III-A.7.5

t_p = transit time required for nuclides to reach the point of exposure. For internal dose, t_p is the total time elapsed between release of the nuclides and ingestion of food or water (hr)

λ_i = radiological decay constant of nuclide i (hr^{-1})

1119 = a constant which converts from (Ci/yr)/(ft^3/sec) to pCi/liter

The terms $\frac{Q_i N_i}{F}$ in Equation 2 define the concentration of nuclide i in the effluent at the point of discharge. The expression $\frac{Q_i N_i}{F} M_p \exp(-\lambda_i t_p)$ yields the concentration at the time that the water is consumed. This latter concentration is the term C_{ip} in Equation 1.

III-A.4.2 Aquatic Foods

Concentrations of radionuclides in aquatic foods are directly related to the concentrations of the nuclides in water. Equilibrium ratios[10,11] between the two concentrations, called bioaccumulation factors in this report, are listed in Table III-A-13. The equation for calculation of internal dose rate from consumption of aquatic food is

$$R_{pr} = 1119 \sum_{i=1}^{136} \frac{Q_i N_i}{F} M_p B_{ip} e^{-\lambda_i t_p} U_p D_{ipr} \qquad (3)$$

where B_{ip} is the bioaccumulation factor for nuclide i via pathway p (pCi/kg per pCi/liter).

III-A.4.3 Shoreline Deposits

The calculation of sediment load, transport and concentrations of radionuclides associated with suspended and deposited materials is a complex problem. One approach to this problem was used in the Year 2000 Study.[3] For the program ARRRG, a simplified scheme for obtaining an order of magnitude estimate of the concentration of shoreline sediments was developed. The concentration of nuclide i in the sediment can be estimated from

$$S_i = K \frac{A_i \left(1-e^{-\lambda_i t_s}\right)}{\lambda_i} \qquad (4)$$

where

S_i = concentration of nuclide i in sediment (pCi/kg)

A_i = concentration of the nuclide i in the water adjacent to the sediment (pCi/liter)

K = assumed constant in units of liter/kg-d

t_s = total time the sediment is exposed to the contaminated water, nominally taken to be the operating lifetime of the facility (hr)

In the original evaluation of the equation, λ_i was chosen to be the radiological decay constant, although the true value should include an unknown "environmental" removal constant. If the presence of a radionuclide in water and sediment is controlled primarily by radioactive equilibrium with its parent nuclide, then the water concentration and half-life of the parent should be used in the equation.

The relationship was tested and the value of K derived from radionuclide concentrations measured in water and sediment samples collected over a period of several years in the Columbia River between Richland, Washington and the river mouth and in Tillamook Bay, Oregon, 75 km (47 miles) south of the river mouth.[12,13] Since the primary use of the equation is to facilitate estimates of the exposure rate from gamma emitters one meter above the sediment, an effective surface contamination was devised. This surface contamination level was taken to be all of the nuclides contained within the top 2.5 cm (1 in.) of sediment.* The dose contribution from the radionuclides below 2.5 cm in depth was ignored. The resulting equation is

$$S_i' = 100\ \tau_i\ A_i\ W\ (1-e^{-\lambda_i t_s}) \tag{5}$$

where

S_i' = "effective" surface contamination (pCi/m^2)
τ_i = radiological half-life of nuclide i (d)
W = shore width factor (unitless)

Shore width factors (derived from data given in Figure 3.1(5) of Reference 14) are summarized in Table III-A-4.

TABLE III-A-4

SHORE WIDTH FACTORS FOR USE IN EQUATIONS 5 AND 6

Exposure Situation	Shore Width Factor (W)
Discharge canal bank	0.1
River shoreline	0.2
Lake shore	0.3
Nominal ocean site	0.5
Tidal basin	1.0
Organisms on surface or in burrow[a]	2.0

(a) Since the radionuclide concentration normally decreases with depth in the mud, the dose to a buried organism is probably no higher than that to one lying on the mud surface.

The combination of Equations 5 and 1 yields the equation below for calculation of radiation dose from exposure to shoreline sediments.

$$R_{pr} = \sum_{i=1}^{136} S_i'\ U_p\ D_{ipr} = 100 \sum_{i=1}^{136} \tau_i\ A_i\ W\ (1-e^{-\lambda_i t_s})\ U_p\ D_{ipr}$$

$$= 111{,}900 \sum_{i=1}^{136} \tau_i\ \frac{Q_i\ N_i}{F}\ M_p\ e^{-\lambda_i t_p}\ W\ (1-e^{-\lambda_i t_s})\ U_p\ D_{ipr} \tag{6}$$

III-A.4.4 Swimming and Boating

The equation for calculation of external dose to the skin and whole body from swimming (water immersion) or boating (water surface) is

$$R_{pr} = 1119 \sum_{i=1}^{136} \frac{Q_i\ N_i}{F\ K_p}\ M_p\ e^{-\lambda_i t_p}\ U_p\ D_{ipr} \tag{7}$$

* Calculated by multiplying the concentration (pCi/kg) by a mass thickness (40 kg/m^2).

where K_p is a geometry correction factor equal to 1 for swimming and 2 for boating.

III-A.5 Dose to Man--Gaseous Pathways

III-A.5.1 Air Submersion

The formulas used to calculate doses from air submersion are Equations 8 and 9 below[15]

$$R_{pr}(x,\theta,d) = \sum_{i=1}^{136} \bar{\chi}_i \, U_p \, D_{ipr} \tag{8}$$

where

$R_{pr}(x,\theta,d)$ = external dose rate from all of the nuclides i via pathway p to organ r of a person located a point x meters from the source in a direction d, averaged over a sector width of θ radians (mrem/yr)

U_p = 8766 hr/yr for air submersion

D_{ipr} = dose factor for nuclide i via pathway p to organ r based on a half-infinite cloud geometry and corrected for the fractional penetration of beta and gamma radiations to the depth of 7 x 10^{-3} cm for skin and 5 cm for total-body (mrem/hr per pCi/m^3)

and

$$\bar{\chi}_i = \sum_{J=1}^{J'} \left(\frac{2}{\pi}\right)^{1/2} \frac{(0.01 f_J)\, 10^{12} Q_i'}{(\sigma_z)_J \, \bar{u}_J \, \theta \, x} \left[\exp\left(-\frac{h^2}{2(\sigma_z)_J^2}\right)\right] \left[\exp\left(-\frac{\lambda_i x}{\bar{u}_J}\right)\right] \tag{9}$$

where

$\bar{\chi}_i$ = annual average concentration (pCi/m^3) of nuclide i at point (x,θ,d)

f_J = percent of time wind blows in direction d under meteorological condition J

10^{12} = picocuries per curie

Q_i' = release rate of nuclide i (Ci/sec)

θ = sector width = 2π/n radians, where the number of sectors n is normally 16

x = downwind distance (meter)

$\bar{u}_J$ = average wind speed for meteorological condition J (meter/sec)

$\frac{x}{\bar{u}_J}$ = travel time of released material to point (x,θ,d) under meteorological condition J (sec)

λ_i = radiological decay constant for nuclide i (sec^{-1})

h = height of effluent release (meter)

$(\sigma_z)_J$ = standard deviation of vertical dispersion under meteorological condition J (meter^2)

J' = number of meteorological conditions ("stability classes")

The standard deviation of vertical dispersion may be derived for the Hanford (Fuguay-Simpson) four-stability-class method from equations[15] or from tables[15] of σ_z versus x by Pasquill stability category. Both the Hanford and the Pasquill formats are programmed into GRONK since raw meteorology data may be given in either format, depending upon the particular system employed at the nuclear facility.

Equation 8 yields the yearly external dose to a person located at point (x,θ,d). The population dose in man-rem/yr is determined by multiplying this dose by the population located within the sector of the annulus of concern. Values of the dose at the point (x,θ,d) are assumed to apply to all individuals located in that sector.

III-A.5.2 Thyroid Doses from Radioiodine

Equation 8 may also be applied to the calculation of thyroid dose from airborne radioiodine. Pathways of importance are inhalation, ingestion of vegetation contaminated via radioiodine deposition on agricultural land, and ingestion of milk from cows which consume such vegetation. The program provides for calculation of thyroid doses to different ages, since the thyroid dose is usually greater to children than to adults.

A standard value for the usage parameter U_p is assumed for each of the above pathways, and standard transfer factors between air, vegetation, cow, milk and humans are assumed. For ease of calculation, these standard values are multiplied into the thyroid dose factors to create a modified dose factor which converts air concentrations of radioiodine directly into dose rate. The user need only consider those parameters which alter the standard usages: grazing season, vegetation growing season and vegetation consumption rates.

Parameters used to derive the thyroid dose factors are derived from the food pathway model used in the Year 2000 Study[3] and are listed in Table III-A-5. The dose factors obtained from these parameters are listed in Tables III-A-6, -7 and -8.*

TABLE III-A-5

METABOLIC PARAMETERS USED IN THE THYROID DOSE FACTORS[3]

Parameter		1 yr	4 yr	14 yr	Adult
Fractional uptake via ingestion, f_w		0.3	0.3	0.3	0.3
Fractional uptake via inhalation, f_a		0.23	0.23	0.23	0.23
Biological half-life in thyroid (d)[(a)]		20	20	50	100
Thyroid mass (g)		2	5	15	20
Thyroid radius (cm)		1.4	2	2.7	3
Inhalation rate (m^3/d)		5.6	7.0	13.5	20
Effective MeV per disintegration[(b)]	^{129}I	0.060	0.061	0.063	0.064
	^{130}I	0.388	0.427	0.472	0.490
	^{131}I	0.206	0.213	0.221	0.224
	^{132}I	0.581	0.624	0.673	0.693
	^{133}I	0.467	0.478	0.491	0.497
	^{134}I	0.779	0.838	0.906	0.934
	^{135}I	0.481	0.514	0.551	0.566

(a) From References 16-20.
(b) Calculated from formulas of Reference 4 and decay schemes of Reference 9.

III-A.6 Dose To Organisms Other Than Man

Pathways of exposure associated with liquid effluents are generally the most significant contributors to radiation dose to organisms other than man, since aquatic organisms can concentrate radionuclides from their water environment either directly or via their food chains. For purposes of calculating equilibrium concentrations of radionuclides, organisms other than man are divided into two classifications: "primary organisms" which are aquatic and for which bioaccumulation factors are available, and "secondary organisms" which feed upon primary organisms.

* NOTE: The thyroid dose factors listed in the sample runs and program listings as well as the thyroid doses in the sample GRONK run are incorrect. The dose factors have been changed since the listings were programmed. The correct values are shown in Tables III-A-6, -7 and -8. The program now calculates doses for a 1-yr old and an adult thyroid.

TABLE III-A-6

FACTORS FOR CONVERTING AIR CONCENTRATIONS OF RADIOIODINE TO THYROID DOSE VIA INHALATION[a]

(mrem/yr per pCi/m^3)

Age	^{129}I	^{130}I	^{131}I	^{132}I	^{133}I	^{134}I	^{135}I
1 yr	21	3.4	20	0.96	6.8	0.49	2.3
4 yr	11	1.9	11	0.52	3.5	0.26	1.3
14 yr	18	1.3	8.5	0.36	2.4	0.18	0.86
Adult	36	1.6	10	0.41	2.7	0.21	0.98

(a) Organic and inorganic forms of radioiodine give the same dose via inhalation.
Factors include a breathing rate for ages 1 yr, 4 yr, 14 yr and adult of 5.6, 7.0, 13.5 and 30 m^3/d, respectively.

TABLE III-A-7

FACTORS FOR CONVERTING AIR CONCENTRATIONS OF RADIOIODINE TO THYROID DOSE VIA MILK[a]

(mrem/yr per pCi/m^3)

Age	^{129}I	^{130}I	^{131}I	^{132}I	^{133}I	^{134}I	^{135}I
1 yr	5800	44	2700	2.3	140	0.47	17
4 yr	2400	19	1100	1.0	59	0.20	7.1
14 yr	2000	7.2	460	0.36	21	0.073	2.5
Adult	2900	5.6	380	0.28	16	0.056	2.0

(a) Factors include the following assumptions:
- Grazing season is 365 d/yr.
- Milk consumption is 1 liter/d for all ages.
- There is no decay between milking and consumption.
- Radioiodine is 100% inorganic (organic forms of radioiodine contribute insignificantly to dose via this pathway).
- Long-term accumulation in the soil is ignored for ^{129}I (adds ~1.4% in 1 yr or 42% in 30 yr).

TABLE III-A-8

FACTORS FOR CONVERTING AIR CONCENTRATIONS OF RADIOIODINE TO THYROID DOSE VIA LEAFY VEGETABLES[a]

(mrem/yr per pCi/m^3)

Age	^{129}I	^{130}I	^{131}I	^{132}I	^{133}I	^{134}I	^{135}I
1 yr	0	0	0	0	0	0	0
4 yr	500	3.1	180	0.17	9.7	0.033	1.2
14 yr	720	2.0	130	0.10	5.7	0.020	0.70
Adult	1400	2.1	140	0.11	6.0	0.021	0.73

(a) Factors include the following assumptions:
- Vegetables are from home gardens.
- There is no decay between garden and table.
- Vegetables are exposed 3 months above ground to air.
- 25% of deposited material remains on vegetables (remainder on ground) with "environmental" half-life of 14 days.
- Radioiodine is 100% inorganic (organic forms of radioiodine contribute insignificantly to dose via this pathway).
- Long-term accumulation in the soil is ignored for ^{129}I (adds ~1.4% in 1 yr or 42% in 30 yr).
- Maximum individual vegetable consumption for ages 1 yr, 4 yr, 14 yr and adult are 0, 32, 54 and 72 kg/yr, respectively.

Radionuclide concentrations for primary organisms can be calculated directly from the water concentrations and bioaccumulation factors. The primary organisms are fish, crustacea, molluscs and plants. Radionuclide concentrations for secondary organisms must be calculated from their diet of primary organisms. Representative secondary birds and mammals were selected such that each primary organism would be in the diet of at least one secondary organism. The predatory birds and mammals commonly selected are herons, raccoons, and muskrats. Also selected are plant-eating ducks.

III-A.6.1 Internal Doses Via Liquid Pathways

The whole body dose rate to an aquatic organism is

$$R_c = 0.0187 \sum_{i=1}^{136} b_{ic} \, \varepsilon_{ic} \tag{10}$$

where R_c = dose rate to whole body of organism c (mrad/yr)

ε_{ic} = effective absorbed energy in MeV per disintegration (dis) for nuclide i in organism c

b_{ic} = specific body burden of nuclide i in organism c (pCi/kg)

0.0187 = conversion factor calculated as follows:

$$\left(3.7 \times 10^{-2} \frac{\text{dis}}{\text{sec-pCi}}\right)\left(3.156 \times 10^{7} \frac{\text{sec}}{\text{yr}}\right)\left(1.6 \times 10^{-6} \frac{\text{erg}}{\text{MeV}}\right)\left(\frac{\text{kg-mrad}}{100\ \text{erg}}\right) = 0.0187 \frac{\text{dis-kg-mrad}}{\text{pCi-yr-MeV}}$$

For a primary organism, b_{ic} is given by

$$b_{ic} = A_i \, B_{ic} = 1119. \frac{Q_i \, N_i}{F} M_p \, e^{-\lambda_i t_p} B_{ic} \tag{11}$$

where the symbols are as given in Sections III-A.4.1 and III-A.4.2.

Combining equations 10 and 11 yields

$$R_c = 20.93 \sum_{i=1}^{136} \frac{Q_i \, N_i}{F} \, M_p \, e^{-\lambda_i t_p} B_{ic} \, \varepsilon_{ic} \tag{12}$$

The whole body dose factor d'_{ik} from nuclide i for a secondary organism k is[1]

$$D'_{ik} = \frac{0.0021 \, (f_w)'_i \, \varepsilon'_{ik} \, (1-e^{-\lambda'_{Ei} t})}{\lambda'_{Ei} \, m'_k} \left(\frac{\text{mrad/yr}}{\text{pCi/yr intake}}\right). \tag{13}$$

where

$(f_w)'_i$ = fraction of ingested nuclide i retained in secondary organism (unitless)

m'_k = mass of secondary organism k (g)

t = period of exposure (hr)

ε'_{ik} = effective absorbed energy in MeV per disintegration for secondary organism k

$\lambda_{Ei} = \lambda_i + \lambda'_{Bi}$ = effective decay constant of nuclide i in secondary organism (hr^{-1}), where

λ'_{Bi} = biological removal constant of nuclide i in secondary organism (hr^{-1})

The parameters $(f_w)'_i$ and λ'_{Ei} are taken to be the same as those for Standard Man because data for other organisms are lacking. Since the dose factors tabulated for the ARRRG program include whole body dose factors for man, an alternate formulation is convenient for Equation 13:

$$D'_{ik} = \frac{\varepsilon'_{ik}}{m'_k} \frac{m'_{man} D'_{i,man}}{\varepsilon_{i,man}} = \frac{\varepsilon'_{ik}}{m'_k} \frac{70{,}000 \, D_{i,man}}{\varepsilon_{i,man}} \qquad (14)$$

where 70,000 g is the total body mass of the adult.

The radiation dose rate to the whole body of the secondary organism expressed in the format of Equation 1 is

$$R'_i = 0.365 \sum_{i=1}^{136} b_{ic} \, P'_{ck} \, D'_{ik} \qquad (15)$$

where P'_{ck} = consumption rate of primary organism c by secondary organism k (g/d)

0.365 = (kg/g) (d/yr)

Substituting the values of b_{ic} and D'_{ik} from Equations 11 and 14, respectively, into Equation 15 yields

$$R'_i = 2.86 \times 10^7 \sum_{i=1}^{136} B_{ic} \frac{Q_i N_i}{F} M_p \, e^{-\lambda_i t_p} \, P'_{ck} \frac{\varepsilon'_{ik} D_{i,man}}{m'_k \, \varepsilon_{i,man}} \qquad (16)$$

where

$2.86 \times 10^7 = (0.365) \, (1119) \, (70{,}000)$.

The values for ε and ε' are determined from the effective radius of the organism. Table III-A-18 tabulates ε for seven effective radii for organisms other than man and for the whole body of man for each of the 136 nuclides. In the absence of site-specific data, the values of the parameters in Table III-A-9 may be used for Equation 16.

III-A.6.2 Other Doses to Aquatic and Terrestrial Animals

Primary and secondary organisms are also exposed via water immersion, water surface, bottom sediment and shoreline silt. Although these doses are usually relatively insignificant, they may be calculated using the methods of Section III-A.4 or by the program ARRRG. For shoreline exposure, a correction must be made for the difference in height of exposure between animals and men. For small organisms this correction factor is 2 and has been incorporated in the shore width factor of 2.0 in Table III-A-4.

Secondary organisms are exposed via air submersion, inhalation, and radiation from materials deposited by air. Air submersion doses are of possible significance, depending upon the particular nuclear facility involved, and may be calculated using the methods of Section III-A.5 or by the program GRONK. Exposure from inhalation and materials deposited by air are usually relatively insignificant. Inhalation doses cannot be calculated directly at this time, since the detailed behavior of inhaled radionuclides in animals is not yet known.

TABLE III-A-9

RECOMMENDED PARAMETERS FOR ORGANISMS OTHER THAN MAN TO BE USED IN LIEU OF SITE-SPECIFIC DATA

Organism	Body Mass (kg)	Effective Radius (cm)	Source of Nuclide	Intake Rate (g/d)	Annual Exposure (hr) Air	Sediment	Immersion	Water Surface
Primary								
Fish	(a)	2	Water	(a)	0	0-8766[b]	8766	
Crustacea	(a)	2	Water	(a)	0	0-8766[b]	8766	
Molluscs	(a)	2	Water	(a)	0	8766		8766
Algae	(a)	2	Water	(a)			8766	
Secondary								
Muskrat	1	6	Plant	100	$\frac{8766}{3}$	$\frac{8766}{3}$	$\frac{8766}{3}$	
Raccoon	12	14	Crustacea & Molluscs	200	8766	$\frac{8766}{4}$		
Heron	4.6	11	Fish	600	8766	$\frac{8766}{3}$		$\frac{8766}{3}$
Duck	1	5	Plant	100	8766	$\frac{8766}{2}$		$\frac{8766}{2}$

(a) Not required for calculation of doses to primary organisms.
(b) The hours spent in contact with the sediments are highly variable.

III-A.7 Computer Programs ARRRG, CRITR and GRONK

III-A.7.1 Introduction

Three programs are written in the Basic Computer language to implement the dose calculation models described. These programs are executed interactively at a conversational terminal and are designed to be used by personnel untrained in programming. The codes print informative messages if a user error is detected and allow the user the opportunity to correct the faulty information. The data files utilized and items calculated by each program are listed in Table III-A-10.

Each program produces a summary output at the teletype, with the user controlling the level of detail in the output. ARRRG and GRONK also create fully detailed output at a high-speed printer to serve as a permanent record of the run.

The programs obtain their information from three sources:

(1) Parameters which are highly variable, such as human diets assumed for the particular locality, reactor coolant flow rate and release height, are entered directly at the time each case is run by interactive questions to be answered by the operator, such as "cooling flow in cfs=?"

(2) Parameters which are applicable only to a given facility are stored once within a file when the information is received from the applicant. This information is then automatically accessed each time a case is run for that facility. For ARRRG and CRITR, the liquid release rates for all facilities are stored on a single large file called REL. For GRONK, a file called Gxxxx, where xxxx stands for the first four letters of the reactor name, contains the radionuclide release rates, the population distribution out to 50 miles in 16 sectors and up to 10 annular rings, and meteorological tables of joint frequency of wind speed and direction by stability class in either Hanford or Pasquill format or both.

(3) Parameters which remain constant for every program run are stored in permanent data files and accessed by the program when needed.

Table III-A-11 describes all permanent files of type (2) and (3) and lists the programs which use them.

TABLE III-A-10

PROGRAMS FOR CALCULATING RADIATION DOSES

Program	Data Files	Item Calculated, Equations Used	Organ Doses Calculated
ARRRG	ARGIN REL	Individual and population doses from ingested water, Equation 2	Whole body, GI-LLI,[a] thyroid, bone
		Individual and population doses from aquatic foods (fish, crustacea, molluscs, plants), Equation 3	Whole body, GI-LLI, thyroid, bone
		Individual and population doses from sediment exposure (shoreline), Equation 6	Skin, whole body[b]
		Individual and population doses from swimming and boating, Equation 7	Skin, whole body
CRITR	ARGIN REL CRITEN	Internal doses to aquatic biota (fish, crustacea, molluscs. plants), Equation 12	Whole body
		Internal doses to predators of aquatic biota, such as ducks, muskrats, raccoons and herons, Equation 16	Whole body
GRONK	GIN TONIC Gxxxx	Annual average atmospheric dilution factors (Ci/m^3 per Ci/sec released) versus distance and direction from the source ($\bar{\chi}/Q'$), Equation 9	---
		Individual doses from exposure to half-infinite cloud of effluents, versus distance and direction from the source, Equation 8	Skin, whole body
		Integrated man-rem doses to total population within 50 miles, Equation 8	Whole body
		Doses to child and adult from inhalation, and consumption of milk and leafy vegetables, Equation 8	Thyroid

(a) GI-LLI means gastrointestinal tract-lower large intestine.
(b) For these pathways, the calculated whole body dose is listed under GI-LLI, thyroid and bone on the printout and is added into the total dose to these organs.

Discussions of ARRRG, CRITR and GRONK are located in Sections III-A.7.2, III-A.7.3 and III-A.7.4, respectively. Table III-A-12 is a guide to the contents of these sections.

Each program discussion includes a teletype printout for a typical run, with input typed by the user* indicated by wavy underlines. Once the user has signed onto the system, he begins execution with the command RUN *name*, where *name* represents ARRRG, CRITR or GRONK. CRITR allows one case to be computed per execution; for additional cases the user enters the command RUN. ARRRG allows any number of cases with varying input to be computed for the specified reactor; to change reactors, the user enters the command RUN. GRONK has no restrictions on changing reactors or on the number of cases per reactor.

* Reactor data files and input parameters chosen for the sample runs are intended only to demonstrate operation of the programs.

TABLE III-A-11

DATA FILES UTILIZED BY THE DOSE CALCULATION PROGRAMS

File	Contents
ARGIN	Decay constants; internal ingestion dose factors for whole body, GI-LLI, thyroid and bone; external dose factors for skin and whole body for exposure to sediment and to water for 136 radionuclides; fresh and salt water bioaccumulation factors for fish, crustacea, molluscs and algae by element.
REL	Radionuclides released with liquid effluents (Ci/yr) for each facility under study.
CRITEN	List of effective absorbed energies per disintegration versus radius for 136 radionuclides.
GIN	Decay constants, external skin and whole body dose factors for air submersion for 136 radionuclides; child and adult thyroid dose factors for inhalation, milk and leafy vegetables.
TONIC	Constants used for the Pasquill meteorology calculation.
Gxxxx[a]	File for a particular facility containing radionuclides released with gaseous effluents (Ci/yr), population distribution out to 50 miles in 16 sectors and up to 10 annular rings, and meteorological data in tables of joint frequency of wind speed, direction and stability class in either Hanford or Pasquill format or both.

(a) Where xxxx represents the first four letters of the facility name.

TABLE III-A-12

INDEX TO PROGRAM DESCRIPTIONS AND LISTINGS

Program Name	Program Description (Section)	Sample Conversational Session (Table)	Input Work Sheet (Table)	Sample High-Speed Printer Output (Table)
ARRRG	III-A.7.2 III-A.7.5	III-A-15	III-A-16	III-A-17
CRITR	III-A.7.3 III-A.7.5	III-A-19	None	None
GRONK	III-A.7.4	III-A-22	III-A-20	III-A-23

Constants may be entered with or without a decimal point or in E format. If more than one constant is to be entered on a line, the values may be separated by either blanks or commas. Questions requiring yes-or-no answers may be answered with either Y, YES, N or NO. Titles and reactor names may be more than one word.

The programs use a common master list of 136 radionuclides. Section III-A.7.6 details the method by which parent-daughter nuclide pairs are treated in the master list. Table III-A-13 is a compilation by nuclide of standard decay constants, bioaccumulation factors and dose factors used in the programs. The Nuclide Release Worksheet (Table III-A-14) is helpful in preparing the release rate input required for REL and Gxxxx files.

Copies of the programs and associated data files may be obtained upon request. These programs are written in the considerably enhanced version of Basic provided by Computer Sciences Corporation for their INFONET time-sharing network. The CSCX operating system is currently available only at the Richland, Washington INFONET installation; the CSTS operating system is in use at all other installations. ARRRG and GRONK are available in both CSCX and CSTS versions; the other programs and files are compatible with either system without change. The sample output reproduced here was created with the CSTS versions of ARRRG and GRONK. The CSCX output shows minor differences in format.

TABLE III-A-13

NUCLIDE MASTER LIST

MASTER LIST OF CONCENTRATION FACTORS

ISOTOPE	LAMBDA 1/SEC	LAMBDA 1/HOURS	SALT WATER CONCENTRATION FACTORS, LITER/KG: FISH	CRUSTACEA	MOLLUSCS	ALGAE	FRESH WATER CONCENTRATION FACTORS, LITER/KG: FISH	CRUSTACEA	MOLLUSCS	ALGAE
1 H-3	1.79E-09	6.43E-06	1	1	1	1	1	1	1	1
2 C-14	3.83E-12	1.38E-08	1	1	1	1	4600	9100	9100	4600
3 N-13	1.16E-03	4.16E+00	0	0	0	0	0	0	0	0
4 F-18	1.04E-04	3.75E-01	4	4	4	1	10	100	100	2
5 NA-22	8.44E-09	3.04E-05	1	1	1	1	100	200	200	500
6 NA-24	1.28E-05	4.62E-02	1	1	1	1	100	200	200	500
7 P-32	5.61E-07	2.02E-03	10000	10000	10000	100000	1,0000[a]	20000	20000	500000
8 AR-39	8.17E-11	2.94E-07	1	1	1	1	1	1	1	1
9 AR-41	1.05E-04	3.79E-01	1	1	1	1	1	1	1	1
10 SC-46	9.56E-08	3.44E-04	100	300	300	1000	2	1000	1000	10000
11 CR-51	2.89E-07	1.04E-03	100	1000	1000	1000	20	2000	2000	4000
12 MN-54	2.65E-08	9.53E-05	3000	10000	50000	10000	400	90000	90000	10000
13 MN-56	7.47E-05	2.69E-01	3000	10000	50000	10000	400	90000	90000	10000
14 FE-55	8.44E-09	3.04E-05	1000	4000	20000	6000	100	3200	3200	1000
15 FE-59	1.78E-07	6.42E-04	1000	4000	20000	6000	100	3200	3200	1000
16 CO-57	2.97E-08	1.07E-04	100	10000	300	100	50	200	200	200
17 CO-58	1.12E-07	4.05E-04	100	10000	300	100	50	200	200	200
18 CO-60	4.17E-09	1.50E-05	100	10000	300	100	50	200	200	200
19 NI-63	2.39E-10	8.60E-07	500	100	100	100	100	100	100	50
20 NI-65	7.53E-05	2.71E-01	500	100	100	100	100	100	100	50
21 CU-64	1.51E-05	5.42E-02	1000	5000	5000	1000	50	400	400	2000
22 ZN-65	3.28E-08	1.18E-04	5000	5000	50000	1000	2000[a]	10000	10000	20000
23 ZN-69M+D	1.39E-05	5.02E-02	5000	5000	50000	1000	2000	10000	10000	20000
24 ZN-69	2.02E-04	7.29E-01	5000	5000	50000	1000	2000	10000	10000	20000
25 BR-82	5.44E-06	1.96E-02	3	10	10	100	420	330	330	50
26 BR-83+D	8.03E-05	2.89E-01	3	10	10	100	420	330	330	50
27 BR-84	3.64E-04	1.31E+00	3	10	10	100	420	330	330	50
28 BR-85	3.86E-03	1.39E+01	3	10	10	100	420	330	330	50
29 KR-83M	1.04E-04	3.73E-01	1	1	1	1	1	1	1	1
30 KR-85M	4.39E-05	1.58E-01	1	1	1	1	1	1	1	1
31 KR-85	2.04E-09	7.35E-06	1	1	1	1	1	1	1	1
32 KR-87	1.52E-04	5.47E-01	1	1	1	1	1	1	1	1
33 KR-88	6.86E-05	2.47E-01	1	1	1	1	1	1	1	1
34 RB-86	4.31E-07	1.55E-03	30	50	10	10	2000	1000	1000	1000
35 RB-88	6.47E-04	2.33E+00	30	50	10	10	2000	1000	1000	1000
36 RB-89	7.50E-04	2.70E+00	30	50	10	10	2000	1000	1000	1000
37 SR-89	1.54E-07	5.55E-04	1	1	1	20	30	100	100	500
38 SR-90	7.78E-10	2.80E-06	1	1	1	20	30	100	100	500
39 SR-90D	7.78E-10	2.80E-06	1	1	1	20	30	100	100	500
40 SR-91	1.99E-05	7.17E-02	1	1	1	20	30	100	100	500
41 SR-92	7.11E-05	2.56E-01	1	1	1	20	30	100	100	500
42 Y-90	3.00E-06	1.08E-02	30	100	100	300	25	1000	1000	5000
43 Y-91M	2.31E-04	8.32E-01	30	100	100	300	25	1000	1000	5000
44 Y-91	1.36E-07	4.91E-04	30	100	100	300	25	1000	1000	5000
45 Y-92	5.44E-05	1.96E-01	30	100	100	300	25	1000	1000	5000
46 Y-93	1.89E-05	6.80E-02	30	100	100	300	25	1000	1000	5000
47 ZR-95	1.23E-07	4.44E-04	30	100	100	1000	330	7	7	1000
48 ZR-95D	1.23E-07	4.44E-04	30	100	100	1000	330	7	7	1000
49 ZR-97	1.13E-05	4.08E-02	30	100	100	1000	330	7	7	1000
50 ZR-97D	1.13E-05	4.08E-02	30	100	100	1000	330	7	7	1000
51 NB-95	2.29E-07	8.25E-04	100	200	200	100	30000	100	100	800
52 NB-97	1.61E-04	5.78E-01	100	200	200	100	30000	100	100	800
53 MO-99+D	2.86E-06	1.03E-02	10	100	100	100	10	10	10	1000
54 MO-99D	2.86E-06	1.03E-02	10	100	100	100	10	10	10	1000
55 TC-99M	3.22E-05	1.16E-01	10	100	100	1000	15	5	5	40
56 TC-99	1.04E-13	3.73E-10	10	100	100	1000	15	5	5	40
57 TC-101	8.25E-04	2.97E+00	10	100	100	1000	15	5	5	40
58 RU-103+D	2.02E-07	7.29E-04	3	100	100	1000	10	300	300	2000
59 RU-105+D	4.33E-05	1.56E-01	3	100	100	1000	10	300	300	2000
60 RU-106+D	2.19E-08	7.87E-05	3	100	100	1000	10	300	300	2000
61 RH-105	5.36E-06	1.93E-02	10	100	100	100	10	300	300	200
62 PD-109+D	1.43E-05	5.15E-02	10	100	100	100	10	300	300	200
63 AG-110M+D	3.17E-08	1.14E-04	1000	5000	5000	1000	2	770	770	200
64 AG-111	1.07E-06	3.85E-03	1000	5000	5000	1000	2	770	770	200
65 SN-125	8.53E-07	3.07E-03	3	3	3	10	3000	1000	1000	100
66 SB-124	1.34E-07	4.81E-04	1000	1000	1000	10000	1	10	10	1500
67 SB-125	8.14E-09	2.93E-05	1000	1000	1000	10000	1	10	10	1500
68 SB-127	2.07E-06	7.46E-03	1000	1000	1000	10000	1	10	10	1500
69 TE-125M	1.38E-07	4.98E-04	10	10	100	1000	400	75	75	100
70 TE-127M	7.36E-08	2.65E-04	10	10	100	1000	400	75	75	100
71 TE-127	2.05E-05	7.37E-02	10	10	100	1000	400	75	75	100
72 TE-129M+D	2.36E-07	8.49E-04	10	10	100	1000	400	75	75	100
73 TE-129	1.68E-04	6.03E-01	10	10	100	1000	400	75	75	100
74 TE-131M	6.42E-06	2.31E-02	10	10	100	1000	400	75	75	100
75 TE-131	4.61E-04	1.66E+00	10	10	100	1000	400	75	75	100
76 TE-132	2.47E-06	8.89E-03	10	10	100	1000	400	75	75	100
77 TE-132D	2.47E-06	8.89E-03	10	10	100	1000	400	75	75	100
78 TE-133M+D	2.31E-04	8.32E-01	10	10	100	1000	400	75	75	100
79 TE-134	2.75E-04	9.89E-01	10	10	100	1000	400	75	75	100
80 I-129	1.29E-15	4.65E-12	20	100	100	10000	15	5	5	40
81 I-130	1.55E-05	5.59E-02	20	100	100	10000	15	5	5	40
82 I-131	9.97E-07	3.59E-03	20	100	100	10000	15	5	5	40
83 I-132	8.36E-05	3.01E-01	20	100	100	10000	15	5	5	40
84 I-133	9.17E-06	3.30E-02	20	100	100	10000	15	5	5	40
85 I-134	2.22E-04	8.00E-01	20	100	100	10000	15	5	5	40
86 I-135	2.86E-05	1.03E-01	20	100	100	10000	15	5	5	40
87 XE-131M	6.81E-07	2.45E-03	1	1	1	1	1	1	1	1
88 XE-133M	3.56E-06	1.28E-02	1	1	1	1	1	1	1	1

(a) For the Hanford Waste Management Environmental Impact Statement the locally measured values of 170 for ^{32}P and 64 for ^{65}Zn in panfish flesh were used.

TABLE III-A-13 (Continued)

89	XE-133	1.52E-06	5.48E-03	1	1	1	1	1	1	1	1
90	XE-135M	7.42E-04	2.67E+00	1	1	1	1	1	1	1	1
91	XE-135	2.09E-05	7.54E-02	1	1	1	1	1	1	1	1
92	XE-137	2.97E-03	1.07E+01	1	1	1	1	1	1	1	1
93	XE-138	6.81E-04	2.45E+00	1	1	1	1	1	1	1	1
94	CS-134M	6.64E-05	2.39E-01	30	50	10	10	2000	100	100	500
95	CS-134	1.07E-08	3.36E-05	30	50	10	10	2000	100	100	500
96	CS-135	7.33E-09	2.64E-05	30	50	10	10	2000	100	100	500
97	CS-136	6.17E-07	2.22E-03	30	50	10	10	2000	100	100	500
98	CS-137	7.31E-10	2.63E-06	30	50	10	10	2000	100	100	500
99	CS-138	3.58E-04	1.29E+00	30	50	10	10	2000	100	100	500
100	CS-139	1.22E-03	4.38E+00	30	50	10	10	2000	100	100	500
101	BA-139	1.39E-04	5.02E-01	3	3	3	100	4	200	200	500
102	BA-140	6.28E-07	2.26E-03	3	3	3	100	4	200	200	500
103	BA-140D	6.28E-07	2.26E-03	3	3	3	100	4	200	200	500
104	BA-141	6.42E-04	2.31E+00	3	3	3	100	4	200	200	500
105	BA-142	1.05E-03	3.78E+00	3	3	3	100	4	200	200	500
106	LA-140	4.78E-06	1.72E-02	30	100	100	300	25	1000	1000	5000
107	LA-141	4.94E-05	1.78E-01	30	100	100	300	25	1000	1000	5000
108	LA-142	1.26E-04	4.52E-01	30	100	100	300	25	1000	1000	5000
109	CE-141	2.43E-07	8.75E-04	30	100	100	300	1	1000	1000	4000
110	CE-143	5.81E-06	2.09E-02	30	100	100	300	1	1000	1000	4000
111	CE-144+D	2.83E-08	1.02E-04	30	100	100	300	1	1000	1000	4000
112	PR-143	5.89E-07	2.12E-03	100	1000	1000	1000	25	1000	1000	5000
113	PR-144	6.69E-04	2.41E+00	100	1000	1000	1000	25	1000	1000	5000
114	ND-147	7.22E-07	2.60E-03	100	1000	1000	1000	25	1000	1000	5000
115	PM-147	8.39E-09	3.02E-05	100	1000	1000	1000	25	1000	1000	5000
116	PM-148	1.49E-06	5.35E-03	100	1000	1000	1000	25	1000	1000	5000
117	PM-149	3.64E-06	1.31E-02	100	1000	1000	1000	25	1000	1000	5000
118	PM-151	6.86E-06	2.47E-02	100	1000	1000	1000	25	1000	1000	5000
119	SM-153	4.08E-06	1.47E-02	100	1000	1000	1000	25	1000	1000	5000
120	EU-156	5.36E-07	1.93E-03	100	1000	1000	1000	25	1000	1000	5000
121	W-181	5.72E-08	2.06E-04	10	10	100	100	1200	10	10	1200
122	W-185	1.07E-07	3.85E-04	10	10	100	100	1200	10	10	1200
123	W-187	8.06E-06	2.93E-02	10	10	100	100	1200	10	10	1200
124	U-237	1.19E-06	4.28E-03	10	10	10	67	2	60	60	1
125	NP-238	3.83E-06	1.38E-02	10	10	10	6	10	400	400	300
126	NP-239	3.42E-06	1.23E-02	10	10	10	6	10	400	400	300
127	PU-238	2.56E-10	9.23E-07	3	200	200	1000	4	100	100	350
128	PU-239	9.03E-13	3.25E-09	3	200	200	1000	4	100	100	350
129	PU-240	3.33E-12	1.20E-08	3	200	200	1000	4	100	100	350
130	PU-241+D	1.66E-09	5.99E-06	3	200	200	1000	4	100	100	350
131	PU-242	5.81E-14	2.09E-10	3	200	200	1000	4	100	100	350
132	AM-241	4.81E-13	1.73E-09	25	1000	1000	5000	25	1000	1000	5000
133	AM-243+D	2.77E-12	9.96E-09	25	1000	1000	5000	25	1000	1000	5000
134	CM-242	4.92E-08	1.77E-04	25	1000	1000	5000	25	1000	1000	5000
135	CM-244	1.25E-09	4.50E-06	25	1000	1000	5000	25	1000	1000	5000
136	CF-252	8.31E-09	2.99E-05	25	1000	1000	5000	25	1000	1000	5000

		BODY	SKIN	[illegible]	GI-LLI	THYROID	BONE	SKIN	POLY	SKIN	BODY
1	H-3	0	0	1.27E-07	1.40E-08	1.27E-07	0	0	0	0	0
2	C-14	1.4E-11	3.5E-09	5.29E-07	1.20E-07	5.29E-07	2.64E-06	0	0	3.00E-09	0
3	N-13	6.5E-07	1.4E-06	0	0	0	0	8.80E-09	7.60E-09	2.60E-06	1.90E-06
4	F-18	6.2E-07	1.1E-06	7.06E-06	1.93E-08	0	6.30E-07	8.00E-09	6.80E-09	2.30E-06	1.80E-06
5	NA-22	1.4E-06	2.3E-06	1.77E-05	3.20E-06	1.77E-05	1.77E-05	1.80E-08	1.60E-08	4.80E-06	4.00E-06
6	NA-24	3.5E-06	4.5E-06	1.71E-06	3.73E-06	1.71E-06	1.71E-06	2.90E-08	2.50E-08	9.30E-06	7.89E-06
7	P-32	5.9E-09	6.2E-07	7.44E-06	2.15E-05	0	1.93E-04	0	0	6.30E-07	6.40E-09
8	AR-39	3.3E-10	1.2E-07	0	0	0	0	0	0	1.30E-07	6.20E-10
9	AR-41	1.1E-06	1.6E-06	0	0	0	0	0	0	3.20E-06	2.40E-06
10	SC-46	1.7E-06	2.3E-06	3.07E-09	5.19E-05	0	5.26E-09	1.50E-08	1.30E-08	4.30E-06	3.70E-06
11	CR-51	2.4E-08	2.9E-08	2.67E-09	2.69E-07	1.59E-09	0	2.60E-10	2.20E-10	6.40E-08	5.20E-08
12	MN-54	7.0E-07	8.1E-07	6.60E-07	1.38E-05	0	0	6.80E-09	5.80E-09	1.30E-06	1.50E-06
13	MN-56	1.5E-06	2.4E-06	2.94E-06	3.60E-06	0	0	1.30E-08	1.10E-08	4.60E-06	3.20E-06
14	FE-55	3.5E-11	1.6E-09	1.48E-07	6.41E-07	0	6.78E-07	0	0	3.60E-10	6.40E-11
15	FE-59	1.3E-06	1.2E-06	3.68E-06	3.31E-05	0	4.12E-06	9.40E-09	8.00E-09	2.60E-06	2.20E-06
16	CO-57	1.0E-07	1.2E-07	2.92E-07	4.47E-06	0	0	1.00E-09	9.10E-10	2.70E-07	2.20E-07
17	CO-58	8.2E-07	1.1E-06	1.66E-06	1.52E-05	0	0	8.20E-09	7.00E-09	2.30E-06	1.80E-06
18	CO-60	2.3E-06	2.5E-06	4.70E-06	3.94E-05	0	0	2.00E-08	1.70E-08	5.40E-06	4.60E-06
19	NI-63	0	0	1.20E-06	1.61E-06	0	3.02E-05	0	0	0	0
20	NI-65	4.8E-07	1.1E-06	6.22E-06	1.90E-06	0	5.46E-07	4.30E-09	3.70E-09	1.90E-06	1.00E-06
21	CU-64	1.7E-07	2.8E-07	6.91E-08	6.85E-06	0	0	1.70E-09	1.50E-09	5.20E-07	3.70E-07
22	ZN-65	4.9E-07	5.6E-07	5.08E-06	9.70E-06	0	3.40E-06	4.60E-09	4.00E-09	1.20E-06	1.10E-06
23	ZN-69M+D	3.4E-07	6.8E-07	3.65E-06	2.49E-05	0	1.65E-07	3.40E-09	2.90E-09	1.20E-06	7.50E-07
24	ZN-69	7.1E-10	2.5E-07	1.34E-09	2.90E-09	0	1.00E-08	0	0	2.80E-07	1.60E-09
25	BR-82	2.4E-06	2.9E-06	2.34E-06	2.53E-06	0	0	2.20E-08	1.90E-08	6.30E-06	5.30E-06
26	BR-83+D	7.5E-09	2.7E-07	3.87E-08	5.61E-08	0	0	9.30E-11	8.40E-11	3.10E-07	1.70E-08
27	BR-84	1.6E-06	3.3E-06	5.26E-08	4.15E-13	0	0	1.40E-08	1.20E-08	5.30E-06	3.50E-06
28	BR-85	6.7E-09	4.7E-07	2.29E-09	0	0	0	0	0	1.10E-06	1.40E-08
29	KR-83M	0	7.0E-10	0	0	0	0	0	0	7.90E-09	3.10E-09
30	KR-85M	1.3E-07	3.2E-07	0	0	0	0	0	0	5.10E-07	2.80E-07
31	KR-85	2.2E-09	1.6E-07	0	0	0	0	0	0	1.80E-07	4.70E-09
32	KR-87	1.3E-06	2.7E-06	0	0	0	0	0	0	4.60E-06	2.70E-06
33	KR-88	1.5E-06	2.3E-06	0	0	0	0	0	0	4.10E-06	3.30E-06
34	RB-86	8.0E-08	6.8E-07	1.60E-05	4.27E-06	0	0	7.20E-10	6.30E-10	8.50E-07	1.70E-07
35	RB-88	5.6E-07	2.7E-06	3.26E-08	0	0	0	4.00E-09	3.50E-09	3.60E-06	1.20E-06
36	RB-89	2.1E-06	2.8E-06	2.86E-08	0	0	0	1.80E-08	1.50E-08	5.80E-06	4.50E-06
37	SR-89	2.1E-09	4.9E-07	9.13E-06	4.90E-05	0	3.20E-04	6.50E-13	5.60E-13	5.40E-07	4.60E-09
38	SR-90	2.4E-10	1.3E-07	8.95E-05	1.23E-04	0	3.36E-04	0	0	1.50E-07	5.40E-10
39	SR-90D	6.1E-09	8.6E-07	2.65E-10	1.05E-04	0	9.86E-09	2.60E-12	2.20E-12	9.60E-07	1.30E-08
40	SR-91	6.9E-07	1.6E-06	2.43E-07	2.87E-05	0	5.82E-06	8.30E-09	7.10E-09	2.70E-06	1.90E-06
41	SR-92	1.1E-06	1.3E-06	9.35E-08	4.31E-05	0	2.16E-06	1.00E-08	9.00E-09	3.10E-06	2.60E-06
42	Y-90	6.1E-09	8.6E-07	2.65E-10	1.05E-04	0	9.86E-09	2.60E-12	2.20E-12	9.60E-07	1.30E-08
43	Y-91M	4.6E-07	5.6E-07	3.46E-12	2.91E-10	0	8.89E-11	4.40E-09	3.80E-09	1.20E-06	1.00E-06
44	Y-91	3.1E-09	5.2E-07	3.60E-09	7.50E-05	0	1.36E-07	2.70E-11	2.40E-11	5.70E-07	6.70E-09
45	Y-92	2.1E-07	1.6E-06	2.50E-11	1.49E-05	0	8.57E-10	1.90E-09	1.60E-09	2.00E-06	4.60E-07
46	Y-93	8.7E-08	1.2E-06	5.53E-11	6.31E-05	0	1.98E-09	7.80E-10	5.70E-10	1.40E-06	1.90E-07
47	ZR-95	6.8E-07	8.4E-07	6.34E-09	2.93E-05	0	2.70E-08	5.80E-09	5.00E-09	1.20E-06	1.50E-06
48	ZR-95D	6.4E-07	7.5E-07	1.81E-09	2.03E-05	0	5.56E-09	6.00E-09	5.10E-09	1.60E-06	1.40E-06
49	ZR-97	6.9E-07	1.4E-06	1.59E-10	1.07E-04	0	1.69E-09	6.40E-09	5.50E-09	2.40E-06	1.50E-06
50	ZR-97D	5.6E-07	1.1E-06	4.70E-12	4.09E-08	0	5.06E-11	5.40E-09	4.60E-09	1.90E-06	1.20E-06
51	NB-95	6.4E-07	7.5E-07	1.81E-09	2.03E-05	0	5.56E-09	6.00E-09	5.10E-09	1.60E-06	1.40E-06
52	NB-97	5.6E-07	1.1E-06	4.70E-12	4.09E-08	0	5.06E-11	5.40E-09	4.60E-09	1.90E-06	1.20E-06
53	MO-99+D	2.2E-07	5.0E-07	7.92E-07	9.85E-06	0	0	2.20E-09	1.90E-09	9.10E-07	4.70E-07
54	MO-99D	1.1E-07	1.3E-07	2.01E-06	2.00E-06	0	1.77E-09	9.50E-10	8.30E-10	2.40E-07	2.10E-07

TABLE III-A-13 (Continued)

55 TC-99M	1.1E-07	1.3E-07	2.01E-06	2.00E-06	0	1.77E-09	1.10E-09	9.60E-10	2.70E-07	2.40E-07
56 TC-99	5.2E-11	2.4E-08	4.44E-06	5.38E-06	0	1.11E-07	0	0	2.60E-10	1.30E-10
57 TC-101	3.0E-07	7.0E-07	3.55E-09	6.54E-22	0	2.51E-10	3.00E-09	2.70E-09	1.20E-06	6.80E-07
58 RU-103+D	4.1E-07	4.9E-07	7.97E-08	2.09E-05	0	1.72E-07	4.20E-09	3.60E-09	1.10E-06	8.90E-07
59 RU-105+D	5.4E-07	1.3E-06	6.03E-09	9.19E-06	0	1.49E-08	5.10E-09	4.50E-09	1.80E-06	1.20E-06
60 RU-106+D	1.7E-07	1.5E-06	3.56E-07	1.81E-04	0	2.79E-06	1.80E-09	1.50E-09	1.90E-06	3.00E-07
61 RH-105	7.8E-08	1.6E-07	5.82E-06	1.36E-05	0	1.15E-07	7.70E-10	6.60E-10	3.00E-07	1.70E-07
62 PD-109+D	4.3E-09	3.3E-07	4.16E-06	2.05E-05	0	0	4.00E-11	3.50E-11	3.40E-07	9.30E-09
63 AG-110M+D	2.2E-06	2.4E-06	6.70E-08	5.82E-05	0	1.46E-07	2.10E-08	1.80E-08	5.30E-06	4.90E-06
64 AG-111	2.2E-06	3.2E-07	1.21E-08	4.34E-05	0	5.74E-08	2.10E-10	1.80E-10	3.30E-07	4.80E-08
65 SN-125	7.3E-08	9.1E-07	3.79E-07	1.06E-04	1.40E-07	8.33E-06	6.60E-10	5.70E-10	1.10E-06	1.60E-07
66 SB-124	1.6E-06	2.2E-06	1.10E-06	7.90E-05	6.74E-09	2.80E-06	1.50E-08	1.30E-08	4.50E-06	3.60E-06
67 SB-125	3.6E-07	4.5E-07	4.17E-07	1.86E-05	1.72E-09	1.57E-06	3.50E-09	3.10E-09	9.50E-07	7.80E-07
68 SB-127	6.7E-07	9.3E-07	1.18E-07	6.54E-05	4.07E-09	3.57E-07	6.60E-09	5.70E-09	1.80E-06	1.50E-06
69 TE-125M	1.7E-09	1.1E-06	3.49E-07	1.05E-05	7.94E-07	2.72E-06	4.80E-11	3.50E-11	1.50E-08	3.60E-09
70 TE-127M	1.2E-10	1.6E-09	7.62E-07	2.10E-05	1.61E-06	6.40E-06	1.30E-12	1.10E-12	1.80E-09	2.60E-10
71 TE-127	1.2E-09	1.6E-07	2.21E-06	8.13E-06	7.53E-08	1.03E-07	1.10E-11	1.00E-11	1.70E-07	2.80E-09
72 TE-129M+D	9.4E-08	5.7E-07	1.77E-06	5.79E-05	4.50E-06	1.17E-05	9.00E-10	7.70E-10	7.40E-07	2.10E-07
73 TE-129	6.7E-08	5.3E-07	7.61E-09	2.12E-08	2.40E-08	3.13E-08	8.40E-10	7.10E-10	7.00E-07	1.90E-07
74 TE-131M	1.0E-06	1.3E-06	4.71E-07	3.84E-05	6.92E-07	8.02E-07	9.90E-09	8.40E-09	2.70E-06	2.20E-06
75 TE-131	3.4E-07	1.1E-06	6.25E-09	3.58E-14	1.63E-08	1.95E-08	2.60E-09	2.20E-09	1.60E-06	7.40E-07
76 TE-132	1.8E-07	2.3E-07	1.54E-06	7.79E-05	1.82E-06	2.56E-06	2.00E-09	1.70E-09	4.30E-07	4.00E-07
77 TE-132D	2.0E-06	2.7E-06	1.96E-07	1.07E-07	7.33E-05	2.08E-07	2.00E-08	1.70E-08	5.50E-06	4.40E-06
78 TE-133M+D	1.8E-06	2.4E-06	2.35E-08	1.45E-09	3.52E-08	4.04E-08	1.70E-08	1.50E-08	5.00E-06	3.90E-06
79 TE-134	1.2E-07	1.9E-07	2.20E-08	4.40E-09	2.85E-08	3.25E-08	1.20E-09	1.00E-09	3.50E-07	2.50E-07
80 I-129	1.1E-09	4.3E-09	6.01E-06	3.07E-07	6.18E-03	2.49E-06	9.60E-12	7.00E-12	6.20E-09	2.30E-09
81 I-130	1.8E-06	2.3E-06	8.77E-07	1.89E-06	2.80E-04	7.44E-07	1.70E-08	1.40E-08	4.80E-06	3.90E-06
82 I-131	3.1E-07	4.9E-07	3.37E-06	1.53E-06	1.86E-03	3.93E-06	3.40E-09	2.80E-09	9.30E-07	6.80E-07
83 I-132	2.0E-06	2.7E-06	1.96E-07	1.07E-07	7.33E-05	2.08E-07	2.00E-08	1.70E-08	5.50E-06	4.40E-06
84 I-133	4.4E-07	8.8E-07	7.62E-07	2.25E-06	4.82E-04	1.43E-06	4.50E-09	3.70E-09	1.50E-06	9.60E-07
85 I-134	2.0E-06	2.9E-06	1.02E-07	2.25E-10	3.73E-05	1.07E-07	1.90E-08	1.60E-08	5.50E-06	4.20E-06
86 I-135	1.5E-06	2.0E-06	4.50E-07	1.41E-06	1.76E-04	5.01E-07	1.40E-08	1.20E-08	4.00E-06	3.30E-06
87 XE-131M	2.6E-09	4.0E-08	0	0	0	0	0	0	5.60E-08	6.20E-09
88 XE-133M	2.7E-08	6.0E-08	0	0	0	0	0	0	1.00E-07	6.00E-08
89 XE-133	2.5E-08	6.9E-08	0	0	0	0	0	0	1.10E-07	5.70E-08
90 XE-135M	3.5E-07	5.0E-07	0	0	0	0	0	0	1.00E-06	7.60E-07
91 XE-135	2.1E-07	4.9E-07	0	0	0	0	0	0	7.90E-07	4.50E-07
92 XE-137	1.2E-07	1.8E-06	0	0	0	0	0	0	2.10E-06	2.70E-07
93 XE-138	1.2E-06	1.7E-06	0	0	0	0	0	0	3.40E-06	2.60E-06
94 CS-134M	7.3E-08	9.1E-08	2.43E-05	1.63E-08	0	2.25E-08	7.30E-10	6.20E-10	1.90E-07	1.60E-07
95 CS-134	1.3E-06	1.7E-06	1.00E-04	2.56E-06	0	5.29E-05	1.40E-08	1.20E-08	3.50E-06	2.90E-06
96 CS-135	2.8E-11	8.0E-09	5.64E-06	3.71E-08	0	1.44E-05	0	0	1.10E-08	6.60E-11
97 CS-136	1.9E-06	2.2E-06	1.81E-05	2.86E-06	0	6.24E-06	1.70E-08	1.50E-08	4.80E-06	4.10E-06
98 CS-137	4.7E-07	7.3E-07	5.66E-05	2.05E-06	0	6.37E-05	4.90E-09	4.20E-09	1.40E-06	1.00E-06
99 CS-138	1.7E-06	3.1E-06	5.49E-08	4.89E-13	0	5.66E-08	2.40E-08	2.10E-08	5.70E-06	4.00E-06
100 CS-139	6.3E-07	2.1E-06	1.97E-08	3.54E-30	0	3.18E-08	7.20E-09	6.30E-09	3.20E-06	1.70E-06
101 BA-139	3.7E-08	6.9E-07	2.08E-09	1.68E-07	0	9.85E-08	2.70E-09	2.40E-09	1.00E-06	7.70E-08
102 BA-140	2.2E-07	4.4E-07	1.33E-06	4.02E-05	0	2.02E-05	2.40E-09	2.10E-09	7.60E-07	4.90E-07
103 BA-140D	1.9E-06	2.7E-06	3.34E-10	9.32E-05	0	2.53E-09	1.70E-08	1.50E-08	5.30E-06	4.10E-06
104 BA-141	5.2E-07	1.6E-06	1.73E-09	1.40E-17	0	5.18E-08	4.90E-09	4.30E-09	2.40E-06	1.10E-06
105 BA-142	1.0E-06	1.6E-06	1.37E-09	0	0	2.20E-08	9.00E-09	7.90E-09	3.00E-06	2.20E-06
106 LA-140	1.9E-06	2.7E-06	3.34E-10	9.32E-05	0	2.53E-09	1.70E-08	1.50E-08	5.30E-06	4.10E-06
107 LA-141	2.3E-09	9.2E-07	2.03E-11	1.24E-05	0	3.90E-10	2.80E-10	2.50E-10	1.90E-06	5.10E-08
108 LA-142	2.0E-06	3.1E-06	1.44E-11	4.10E-07	0	1.29E-10	1.80E-08	1.50E-08	5.90E-06	4.50E-06
109 CE-141	5.9E-08	1.5E-07	6.88E-10	2.28E-05	0	8.83E-09	6.20E-10	5.50E-10	2.40E-07	1.30E-07
110 CE-143	2.6E-07	6.3E-07	1.33E-10	4.39E-05	0	1.60E-09	2.50E-09	2.20E-09	1.00E-06	5.70E-07
111 CE-144+D	4.0E-08	1.2E-06	1.98E-08	1.69E-04	0	3.27E-07	3.70E-10	3.20E-10	1.40E-06	8.60E-08
112 PR-143	7.5E-10	2.5E-07	4.39E-10	3.86E-05	0	8.96E-09	0	0	2.80E-07	1.60E-09
113 PR-144	2.0E-08	1.2E-06	1.59E-12	4.51E-18	0	3.13E-11	2.30E-10	2.00E-10	1.30E-06	5.60E-08
114 ND-147	1.3E-07	3.1E-07	4.02E-10	3.34E-05	0	5.43E-09	1.20E-09	1.00E-09	5.00E-07	2.80E-07
115 PM-147	3.3E-11	1.2E-08	1.22E-09	7.93E-06	0	2.36E-08	0	0	1.30E-08	7.50E-11
116 PM-148	5.2E-07	1.2E-06	6.11E-10	9.43E-05	0	7.29E-09	5.30E-09	4.60E-09	2.30E-06	1.10E-06
117 PM-149	6.9E-09	3.1E-07	6.64E-11	4.00E-05	0	1.50E-09	2.90E-11	2.50E-11	3.50E-07	1.50E-08
118 PM-151	2.3E-07	5.3E-07	6.06E-11	3.35E-05	0	7.23E-10	2.30E-09	2.20E-09	8.40E-07	5.00E-07
119 SM-153	3.0E-08	2.3E-07	5.98E-11	2.86E-05	0	9.86E-10	3.00E-10	2.70E-10	2.50E-07	6.50E-08
120 EU-156	9.0E-07	1.5E-06	1.69E-09	7.24E-05	0	1.36E-08	8.70E-09	7.60E-09	2.50E-06	2.10E-06
121 W-181	2.5E-10	3.2E-10	3.49E-10	3.60E-07	0	1.01E-08	2.80E-12	2.10E-12	6.80E-10	5.30E-10
122 W-185	1.4E-10	7.2E-08	1.48E-08	1.60E-05	0	4.26E-07	0	0	7.40E-08	3.20E-10
123 W-187	3.8E-07	6.3E-07	2.12E-08	3.01E-05	0	1.11E-07	3.60E-09	3.10E-09	1.20E-06	8.30E-07
124 U-237	1.2E-07	1.6E-07	1.47E-10	1.94E-05	0	5.53E-10	1.30E-09	1.00E-09	3.40E-07	2.60E-07
125 NP-238	3.5E-07	5.7E-07	2.11E-10	3.43E-05	0	4.27E-09	3.20E-09	2.80E-09	1.10E-06	7.70E-07
126 NP-239	1.1E-07	2.1E-07	6.46E-11	2.40E-05	0	1.20E-09	1.10E-09	9.50E-10	3.70E-07	2.40E-07
127 PU-238	6.8E-11	1.7E-09	4.39E-07	7.30E-05	0	1.76E-05	1.60E-11	1.30E-12	4.00E-09	1.50E-10
128 PU-239	5.6E-11	7.6E-10	4.12E-07	6.66E-05	0	1.65E-05	7.70E-12	7.90E-13	1.70E-09	1.20E-10
129 PU-240	6.5E-11	1.7E-09	4.16E-07	6.78E-05	0	1.65E-05	1.80E-11	1.30E-12	4.00E-09	1.40E-10
130 PU-241+D	2.8E-11	4.2E-11	4.21E-10	6.78E-07	0	1.44E-08	6.80E-12	4.60E-12	9.50E-11	6.10E-11
131 PU-242	5.1E-11	1.6E-09	3.92E-07	6.53E-05	0	1.57E-05	1.60E-11	1.10E-12	3.60E-09	1.10E-10
132 AM-241	1.8E-08	2.7E-08	1.46E-06	7.42E-05	0	1.83E-05	2.60E-10	1.80E-10	6.10E-08	3.90E-08
133 AM-243+D	1.4E-07	2.5E-07	1.41E-06	9.73E-05	0	1.77E-05	1.50E-09	1.30E-09	4.60E-07	3.10E-07
134 CM-242	1.6E-10	2.1E-09	8.26E-07	7.92E-05	0	1.25E-05	2.30E-11	5.50E-12	4.70E-09	3.40E-10
135 CM-244	1.2E-10	1.7E-09	1.51E-06	7.55E-05	0	2.28E-05	1.80E-11	2.90E-12	3.90E-09	2.60E-10
136 CF-252	6.6E-06	7.9E-06	1.16E-06	2.88E-04	0	4.65E-05	7.20E-08	6.60E-08	1.70E-05	1.40E-05

TABLE III-A-13 (Continued)

MASTER LIST OF THYROID DOSE FACTORS[a]

ISOTOPE	MREM/YEAR PER PCI/CUBIC METER					
	---INHALATION---		----M I L K-----		LEAFY VEGETABLES	
	2 YEAR	ADULT	2 YEAR	ADULT	2 YEAR	ADULT
77 TE-132D	0.	0.	126.	9.11	4.04	1.17
80 I-129	5.74	34.3	3600.	3140.	1485.	5190.
81 I-130	2.88	1.57	83.	6.61	26.8	8.53
82 I-131	12.5	10.6	3620.	448.	1190.	589.
83 I-132	0.835	0.414	4.58	0.330	1.48	0.428
84 I-133	5.51	2.70	262.	18.7	84.1	24.1
85 I-134	0.424	0.209	0.911	0.0655	0.293	0.0844
86 I-135	2.00	0.985	31.2	2.28	10.0	2.94

(a) The thyroid dose factors listed in the sample runs and program listings, and the thyroid doses calculated in the sample GRONK are incorrect. The dose factors have been changed since the listings were prepared. The correct values are shown in Tables III-A-6, -7 and -8. The program now calculates thyroid doses for a 1-yr old and an adult.

TABLE III-A-14

NUCLIDE RELEASE WORKSHEET

1 H-3	35 RB-88	69 TE-125M	103 BA-140D
2 C-14	36 RB-89	70 TE-127M	104 BA-141
3 N-13	37 SR-89	71 TE-127	105 BA-142
4 F-18	38 SR-90	72 TE-129M+D	106 LA-140
5 NA-22	39 SR-90D	73 TE-129	107 LA-141
6 NA-24	40 SR-91	74 TE-131M	108 LA-142
7 P-32	41 SR-92	75 TE-131	109 CE-141
8 AR-39	42 Y-90	76 TE-132	110 CE-143
9 AR-41	43 Y-91M	77 TE-132D	111 CE-144+D
10 SC-46	44 Y-91	78 TE-133M+D	112 PR-143
11 CR-51	45 Y-92	79 TE-134	113 PR-144
12 MN-54	46 Y-93	80 I-129	114 ND-147
13 MN-56	47 ZR-95	81 I-130	115 PM-147
14 FE-55	48 ZR-95D	82 I-131	116 PM-148
15 FE-59	49 ZR-97	83 I-132	117 PM-149
16 CO-57	50 ZR-97D	84 I-133	118 PM-151
17 CO-58	51 NB-95	85 I-134	119 SM-153
18 CO-60	52 NB-97	86 I-135	120 EU-156
19 NI-63	53 MO-99+D	87 XE-131M	121 W-181
20 NI-65	54 MO-[illegible]	88 XE-133M	122 W-185
21 CU-64	55 TC-99M	89 XE-133	123 W-187
22 ZN-65	56 TC-99	90 XE-135M	124 U-237
23 ZN-69M+D	57 TC-101	91 XE-135	125 NP-236
24 ZN-69	58 RU-103+D	92 XE-137	126 NP-239
25 BR-82	59 RU-105+D	93 XE-138	127 PU-238
26 BR-83+D	60 RU-106+D	94 CS-134M	128 PU-239
27 BR-84	61 RH-105	95 CS-134	129 PU-240
28 BR-85	62 PD-109+D	96 CS-135	130 PU-241+D
29 KR-83M	63 AG-110M+D	97 CS-136	131 PU-242
30 KR-85M	64 AG-111	98 CS-137	132 AM-241
31 KR-85	65 SN-125	99 CS-[illegible]	133 AM-243+D
32 KR-87	66 SB-124	100 CS-13[illegible]	134 CM-242
33 KR-88	67 SB-125	101 BA-139	135 CM-244
34 RB-[illegible]	68 SB-127	102 BA-140	136 CF-252

Warning to non-INFONET potential users: the authors studied the possibility of converting ARRRG, CRITR and GRONK to the IBM 360-370 series and to the CDC 6600 series and found that many of the features used in these programs are lacking in the Basic of these other computers. Thus, the authors concluded that these programs are not convertible into IBM and CDC Basic. Presumably, this conclusion would hold true for most other computers and time-sharing companies.

III-A.7.2 Program ARRRG

ARRRG (Aqueous Reactor Release Result Generator) calculates annual individual and population doses resulting from radionuclides released with liquid effluents. The calculation is performed using the equations of Section III-A.4 for doses received via any user-selected combination of eight exposure pathways: ingesting fish, molluscs, crustacea and marine plants; drinking water; standing on contaminated shoreline; and swimming and boating in contaminated water.

Internal radiation doses along the fish, crustacea, molluscs, marine-plants and drinking-water pathways are computed for four organs of reference: whole body, GI-LLI, thyroid and bone. External radiation doses along the shoreline,* swimming and boating pathways are computed for two organs of reference: skin and whole body. These external whole body doses are also listed under GI-LLI, thyroid and bone, and are included in the totals for these organs.

Program output at the user's conversational terminal consists of the total dose by pathway and organ, and an optional table of the percent contribution to the total dose by nuclide for each pathway-organ combination. A more detailed output is automatically sent to a high-speed printer. The printout includes the above information plus 1) the section of the REL file containing the releases for the specified facility, 2) tables of dose factors, bioaccumulation factors, decay constants, concentrations of radionuclides in the liquid effluent, and 3) a copy of the parameters entered by the user at the time of the run.

ARRRG obtains its data from three sources:

(1) The holdups, usages and mixing ratios by pathway, the reactor coolant flow, shoreline width factor, and the reconcentration factor parameters are entered by the user at the time of the run. Section III-A.7.5 discusses the choice of parameters to use for the reconcentration factor and mixing ratios. The standard input to be used for the other parameters in absence of information specific to the site is given in Table III-A-3.

(2) The radionuclide release rates for all facilities are stored on a single large file called REL. Release rates for the given facility are stored once within REL at the time the information is received from the applicant; this is the only file ever modified by the user of ARRRG and CRITR. ARRRG automatically accesses that portion of REL headed by the facility name entered by the user at the time the run is made. There is no limit to the number of facilities and they may be in any order, although facility names must be unique. Each facility within REL requires:

- A line containing the facility name, optionally followed comments. This line is printed as part of the heading on the first page and on the top of each result page.
- The word SALT or FRESH to indicate which set of bioaccumulation factors to use.
- The 136 liquid releases (Ci/yr) in the nuclide order given in Table III-A-13. Isotopes which are not released must be listed as zero, but ARRRG accepts the shorthand notation rZ to represent r consecutive zero releases.
- A blank line of one or more spaces.

(3) The 136 nuclide names, decay constants, dose factors, and fresh and salt water bioaccumulation factors required by ARRRG are stored in the permanent file ARGIN.

Table III-A-15 shows teletype printout for a typical run, with user input indicated by wavy underlines. The worksheet of Table III-A-16 is helpful in preparing the input. The reactor name determines which set of releases from REL will be accessed by the program. The user must specify a population dose or an individual dose calculation. If a population dose calculation is specified, the user enters yearly usages for the entire population of interest; dose will be calculated in man-rem/year and appropriate table titles will be printed. If an individual dose calculation

* For the shoreline calculation (Equation 6), the operating lifetime of the facility t_s is taken to be 40 years.

TABLE III-A-15

TELETYPE PRINTOUT FOR SAMPLE ARRRG RUN

```
RUN ARRRG

ARRRG   12:49   01/14/74

REACTOR NAME?PIXES PEAK
DOSE TO POPULATION OR INDIVIDUAL (P OR I)?I
ENTER HOLDUP IN HOURS, USAGES, MIXING RATIOS
 FISH?24 33.6 .03
 CRUSTACEA?0 0 0
 MOLLUSCS?0 0 0
 ALGAE?0 0 0
 DRINKING WATER?24 1430 .03
 SHORELINE?5 106 .14
 SWIMMING?5 416 .14
 BOATING?5 416 .14
SHORE WIDTH FACTOR=?.5
COOLANT FLOW IN CFS=?790
WHICH RECONCENTRATION FORMULA?3

PIXES PEAK    FLOW= 790   CONSTANT RECONCENTRATION= 1
  PLANT LIFE= 30 YEARS   SHORE WIDTH FACTOR= .5

          HOLDUP USAGE MIXING
FISH        24    33.6   .03
DRINKING    24    1430   .03
SHORELINE   5     106    .14
SWIMMING    5     416    .14
BOATING     5     416    .14

CONSTANTS OK?YES
PRINT PERCENTS AT TELETYPE?Y
ENTER TITLE FOR THIS CASE?SAMPLE ARRRG RUN

     * * *  ISOTOPES CONTRIBUTING AT LEAST 4%  * * *

-TOTAL BODY--   ---GI-LLI----   ---THYROID---   ----BONE-----
FISH
CS-134    64%   H-3         5%  I-131     87%   CS-134    47%
CS-137    31%   TE-129M+    6%  I-133     12%   CS-137    49%
                TE-132     38%
                CS-134     18%
                CS-136      5%
                CS-137     12%

DRINKING WATER
H-3       91%   H-3        88%  I-131     85%   I-131     54%
I-131      4%                   I-133     11%   I-133     10%
                                                CS-134    16%
                                                CS-137    17%

----SKIN-----   -TOTAL BODY--
SHORELINE
CS-134    29%   CS-134    29%
CS-137    64%   CS-137    64%

SWIMMING
I-131     26%   I-131     27%
I-132      4%   I-132      5%
I-133     39%   I-133     35%
I-135     20%   I-135     23%

BOATING
      SAME AS SWIMMING

     * * *  INDIVIDUAL DOSE IN MREM/YR  * * *

              SKIN      BODY     GI-LLI   THYROID    BONE
FISH                  1.64E-02 1.51E-03 7.56E-02 1.18E-02
DRINKING              8.45E-03 4.42E-03 2.20E-01 7.29E-04

SHORELINE   1.40E-03 1.20E-03 1.20E-03 1.20E-03 1.20E-03
SWIMMING    5.15E-04 3.68E-04 3.68E-04 3.68E-04 3.68E-04
BOATING     2.57E-04 1.84E-04 1.84E-04 1.84E-04 1.84E-04

TOTALS      2.18E-03 2.66E-02 7.69E-03 2.97E-01 1.43E-02

RUN ANOTHER CASE?N

NOW AT END
SRU'S:6.6
READY
```

is specified, the user enters individual yearly usages; dose will be calculated in mrem/year and appropriate table titles will be printed. For a population dose calculation, specific site data is used for consumption of aquatic foods and hours of recreation. In the absence of such information, default data on per capita usage such as in Table III-A-3 are multiplied by the population living within a 50-mile radius of the site.

The holdup, mixing ratio and usage parameters are then entered by pathway. For unused pathways 0 0 0 is entered. Usages are in the units kg/yr for the four food pathways, liter/yr for the drinking water pathway, and hr/yr for the shoreline, swimming and boating pathways. After the user enters shoreline width, coolant flow and reconcentration data, the program summarizes the input for the user to check. If the response to "constants OK?" is N or NO, the user is permitted to re-enter all the parameters.

The program prints a table of dose by pathway and organ, and prints totals by organ. At the user's option, a table of percent contribution to the total dose by nuclide is printed for each pathway-organ combination. If the user responds Y or YES to "run another case?", he may run ARRRG for the same facility with a different set of input constants.

TABLE III-A-16

ARRRG INPUT WORKSHEET

REACTOR NAME ____________________

☐ POPULATION or ☐ INDIVIDUAL dose calculation

	HOLDUP	USAGE	MIXING RATIO
Fish	______ hr	______ kg/yr	______
Crustacea	______ hr	______ kg/yr	______
Molluscs	______ hr	______ kg/yr	______
Plants	______ hr	______ kg/yr	______
Drinking water	______ hr	______ ℓ/yr	______
Shoreline	______ hr	______ hr/yr	______
Swimming	______ hr	______ hr/yr	______
Boating	______ hr	______ hr/yr	______

SHORE WIDTH FACTOR __________ COOLANT FLOW __________ cfs

RECONCENTRATION MODELS

☐ 1 Simplified theoretical model

VOLUME __________ ft^3 TURNOVER RATE __________ day^{-1}

MAKEUP FLOW __________ cfs CYCLE TIME __________ hr

☐ 2 Empirical model

RECYCLE FRACTION __________ CYCLE TIME __________ hr

☐ 3 No reconcentration

TITLE FOR THIS CASE ______________________________

REMARKS:

Table III-A-17 shows the high-speed printer output resulting from this run. On the last page is a summary of all cases contained in the printout.

III-A.7.3 Program CRITR

CRITR calculates annual internal whole body doses to organisms resulting from radionuclides ingested with their food, using Equations 12 and 16. CRITR always calculates the internal dose to four primary organisms which are directly exposed to the radionuclides in the water: fish, crustacea, molluscs and algae. At the user's option, internal dose can also be calculated for up to six secondary organisms which feed upon one of the primary organisms.

Program output at the user's terminal consists of internal dose to all four primary organisms of the selected organ radius, internal dose to the selected secondary organisms, optional percentage contribution to internal dose by nuclide for each selected primary and secondary organism, and an optional table of release rates and concentrations of radionuclides in the liquid effluent by nuclide. CRITR produces no high-speed printer output.

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TABLE III-A-17

HIGH SPEED PRINTER OUTPUT FOR SAMPLE ARRRG RUN

ARRRG ** ARRRG ** ARRRG ** ARRRG ** ARRRG   01/14/74   12:49   ARRRG ** ARRRG ** ARRRG ** ARRRG ** ARRRG

LISTING OF PIKES PEAK PORTION OF REL FILE:

```
PIKES PEAK
 FRESH 1000 0 0 0 0 0 0 0 0 0 5.7E-4 6.1E-4 0 1.3E-3 6.6E-4 0
 6.9E-3 5.6E-4 0 0 0 0 0 0 9.6E-4 3.4E-3 4.9E-5 0 0 0 0 0 0 6.2E-5
 2.1E-2 1.1E-5 3.6E-4 1.3E-5 1.3E-5 2.4E-4 1.1E-5 1.9E-5 1.5E-4
 3.4E-3 4.1E-5 4.3E-5 6E-5 6E-5 1.7E-5 1.7E-5 6.3E-5 1.8E-5 .26
 .23 .21 0 0 4E-5 5.8E-6 1.3E-5 1.5E-5 1.4E-6 0 7E-7 0 0 0 1.4E-6
 3.3E-5 2.9E-4 2.9E-4 2.6E-3 1.8E-3 1.2E-3 2.4E-4 1.6E-2 1.6E-2
 7.8E-6 6.3E-6 0 6.2E-3 1.6 .21 1.9 2E-3 .52 0 0 0 0 0 0 0 1.4E-5
 .037 0 9E-3 3.2E-2 1.5E-4 5.1E-6 1.5E-4 3.3E-4 3.3E-4 0 0 2E-4
 3.3E-5 7.1E-7 6E-5 2.5E-5 5.1E-5 4.4E-5 0 1.8E-5 2.9E-6 6.5E-6
 8.6E-6 2.5E-6 4.6E-6 2.3E-6 0 0 0 1.1E-5 2.4E-6 3.4E-4 0 0 0
 1.8E-6 0 0 0 0 0 0
```

01/14/74

ISOTOPE	LAMBDA 1/HOURS	INITIAL RELEASE CI/YR	RECON. FACTOR	CONC. PCI/LITER	BIOACCUMULATION FACTORS, L/KG FISH	CRUS-TACEA	MOL-LUSCS	ALGAE
1 H-3	6.43E-06	1.00E+03	1.00	1.42E+03	1	1	1	1
11 CR-51	1.04E-03	5.70E-04	1.00	8.07E-04	20	2000	2000	4000
12 MN-54	9.53E-05	6.10E-04	1.00	8.64E-04	400	90000	90000	10000
14 FE-55	3.04E-05	1.30E-03	1.00	1.84E-03	100	3200	3200	1000
15 FE-59	6.42E-04	6.60E-04	1.00	9.35E-04	100	3200	3200	1000
17 CO-58	4.05E-04	6.90E-03	1.00	9.77E-03	50	200	200	200
18 CO-60	1.50E-05	5.60E-04	1.00	7.93E-04	50	200	200	200
25 BR-82	1.96E-02	9.60E-04	1.00	1.36E-03	420	330	330	50
26 BR-83+D	2.89E-01	3.40E-03	1.00	4.82E-03	420	330	330	50
27 BR-84	1.31E+00	4.90E-05	1.00	6.94E-05	420	330	330	50
34 RB-86	1.55E-03	6.20E-05	1.00	8.78E-05	2000	1000	1000	1000
35 RB-88	2.33E+00	2.10E-02	1.00	2.97E-02	2000	1000	1000	1000
36 RB-89	2.70E+00	1.10E-05	1.00	1.56E-05	2000	1000	1000	1000
37 SR-89	5.55E-04	3.60E-04	1.00	5.10E-04	30	100	100	500.
38 SR-90	2.80E-06	1.30E-05	1.00	1.84E-05	30	100	100	500
39 SR-90D	2.80E-06	1.30E-05	1.00	1.84E-05	30	100	100	500
40 SR-91	7.17E-02	2.40E-04	1.00	3.40E-04	30	100	100	500
41 SR-92	2.56E-01	1.10E-05	1.00	1.56E-05	30	100	100	500
42 Y-90	1.08E-02	1.90E-05	1.00	2.69E-05	25	1000	1000	5000
43 Y-91M	8.32E-01	1.50E-04	1.00	2.12E-04	25	1000	1000	5000
44 Y-91	4.91E-04	3.40E-03	1.00	4.82E-03	25	1000	1000	5000
45 Y-92	1.96E-01	4.10E-05	1.00	5.81E-05	25	1000	1000	5000
46 Y-93	6.80E-02	4.30E-05	1.00	6.09E-05	25	1000	1000	5000
47 ZR-95	4.44E-04	6.00E-05	1.00	8.50E-05	330	7	7	1000
48 ZR-95D	4.44E-04	6.00E-05	1.00	8.50E-05	330	7	7	1000
49 ZR-97	4.08E-02	1.70E-05	1.00	2.41E-05	330	7	7	1000
50 ZR-97D	4.08E-02	1.70E-05	1.00	2.41E-05	330	7	7	1000
51 NB-95	8.25E-04	6.30E-05	1.00	8.92E-05	30000	100	100	800
52 NB-97	5.78E-01	1.80E-05	1.00	2.55E-05	30000	100	100	800
53 MO-99+D	1.03E-02	2.60E-01	1.00	3.68E-01	10	10	10	1000
54 MO-99D	1.03E-02	2.30E-01	1.00	3.26E-01	10	10	10	1000
55 TC-99M	1.16E-01	2.10E-01	1.00	2.97E-01	15	5	5	40
58 RU-103+D	7.29E-04	4.00E-05	1.00	5.67E-05	10	300	300	2000
59 RU-105+D	1.56E-01	5.80E-06	1.00	8.22E-06	10	300	300	2000
60 RU-106+D	7.87E-05	1.30E-05	1.00	1.84E-05	10	300	300	2000
61 RH-105	1.93E-02	1.50E-05	1.00	2.12E-05	10	300	300	200
62 PD-109+D	5.15E-02	1.40E-06	1.00	1.98E-06	10	300	300	200
64 AG-111	3.85E-03	7.00E-07	1.00	9.92E-07	2	770	770	200
68 SB-127	7.46E-03	1.40E-06	1.00	1.98E-06	1	10	10	1500
69 TE-125M	4.98E-04	3.30E-05	1.00	4.67E-05	400	75	75	100
70 TE-127M	2.65E-04	2.90E-04	1.00	4.11E-04	400	75	75	100
71 TE-127	7.37E-02	2.90E-04	1.00	4.11E-04	400	75	75	100
72 TE-129M+D	8.49E-04	2.80E-03	1.00	3.97E-03	400	75	75	100
73 TE-129	6.03E-01	1.80E-03	1.00	2.55E-03	400	75	75	100
74 TE-131M	2.31E-02	1.20E-03	1.00	1.70E-03	400	75	75	100
75 TE-131	1.65E+00	2.40E-04	1.00	3.40E-04	400	75	75	100
76 TE-132	8.49E-03	1.60E-02	1.00	2.27E-02	400	75	75	100
77 TE-132D	8.84E-03	1.60E-02	1.00	2.27E-02	400	75	75	100
78 TE-133M+D	8.32E-01	7.80E-06	1.00	1.10E-05	400	75	75	100
79 TE-134	9.89E-01	8.30E-06	1.00	8.92E-06	400	75	75	100
81 I-130	5.59E-02	6.20E-03	1.00	8.78E-03	15	5	5	40
82 I-131	3.59E-03	1.80E+00	1.00	2.55E+00	15	5	5	40
83 I-132	3.01E-01	2.10E-01	1.00	2.97E-01	15	5	5	40
84 I-133	3.30E-02	1.90E+00	1.00	2.69E+00	15	5	5	40
85 I-134	8.00E-01	2.00E-03	1.00	2.83E-03	15	5	5	40
86 I-135	1.03E-01	5.20E-01	1.00	7.37E-01	15	5	5	40
94 CS-134M	2.39E-01	1.40E-05	1.00	1.98E-05	2000	100	100	500
95 CS-134	3.86E-05	3.70E-02	1.00	5.24E-02	2000	100	100	500
97 CS-136	2.22E-03	9.00E-03	1.00	1.27E-02	2000	100	100	500
98 CS-137	2.63E-06	3.20E-02	1.00	4.53E-02	2000	100	100	500
99 CS-138	1.29E+00	1.50E-04	1.00	2.12E-04	2000	100	100	500
100 CS-139	4.38E+00	5.10E-06	1.00	7.22E-06	2000	100	100	500
101 BA-139	5.02E-01	1.50E-04	1.00	2.12E-04	4	200	200	500
102 BA-140	2.26E-03	3.30E-04	1.00	4.67E-04	4	200	200	500
103 BA-140D	2.26E-03	3.30E-04	1.00	4.67E-04	4	200	200	500
106 LA-140	1.72E-02	2.00E-04	1.00	2.83E-04	25	1000	1000	5000
107 LA-141	1.78E-01	3.30E-05	1.00	4.67E-05	25	1000	1000	5000
108 LA-142	4.52E-01	7.10E-07	1.00	1.01E-06	25	1000	1000	5000
109 CE-141	4.75E-04	6.00E-05	1.00	8.50E-05	1	1000	1000	4000
110 CE-143	2.09E-02	2.50E-05	1.00	3.54E-05	1	1000	1000	4000
111 CE-144+D	1.02E-04	5.10E-05	1.00	7.22E-05	1	1000	1000	4000
112 PR-143	2.12E-03	4.40E-05	1.00	6.23E-05	25	1000	1000	5000

TABLE III-A-17 (Continued)

114 ND-147	2.60E-03	1.60E-05	1.00	2.55E-05	25	1000	1000	5000
115 PM-147	3.02E-05	2.90E-06	1.00	4.11E-06	25	1000	1000	5000
116 PM-148	5.35E-03	6.50E-06	1.00	9.21E-06	25	1000	1000	5000
117 PM-149	1.31E-02	8.60E-06	1.00	1.25E-05	25	1000	1000	5000
118 PM-151	2.47E-02	2.50E-06	1.00	3.54E-06	25	1000	1000	5000
119 SM-153	1.47E-02	4.60E-06	1.00	6.52E-06	25	1000	1000	5000
120 EU-156	1.93E-03	2.30E-06	1.00	3.26E-06	25	1000	1000	5000
124 U-237	4.24E-03	1.10E-05	1.00	1.56E-05	2	60	60	1
125 NP-238	1.30E-02	2.40E-06	1.00	3.40E-06	10	400	400	300
126 NP-239	1.23E-02	3.40E-04	1.00	4.82E-04	10	400	400	300
130 PU-241+D	5.99E-06	1.80E-06	1.00	2.55E-06	4	100	100	350

01/14/74

	A D U L T	D O S E	F A C T O R S					
	I N G E S T I O N				S H O R E L I N E		S W I M M I N G	
ISOTOPE	BODY	GI-LLI	THYROID	BONE	SKIN	BODY	SKIN	BODY
1 H-3	1.27E-07	6.40E-05	1.27E-07	.00E+00	.00E+00	.00E+00	.00E+00	.00E+00
11 CR-51	2.67E-09	6.69E-07	1.59E-09	.00E+00	2.60E-10	2.20E-10	6.40E-08	5.20E-08
12 MN-54	4.65E-07	1.30E-05	.00E+00	.00E+00	6.60E-09	5.80E-09	1.80E-06	1.50E-06
14 FE-55	1.48E-07	6.41E-07	.00E+00	6.78E-07	.00E+00	.00E+00	3.60E-10	6.40E-11
15 FE-59	3.60E-06	3.31E-05	.00E+00	4.12E-06	9.40E-09	8.00E-09	2.60E-06	2.20E-06
17 CO-58	1.68E-06	1.52E-05	.00E+00	.00E+00	8.20E-09	7.00E-09	2.30E-06	1.80E-06
18 CO-60	4.70E-06	3.94E-05	.00E+00	.00E+00	2.00E-08	1.70E-08	5.40E-06	4.60E-06
25 BR-82	2.34E-06	2.53E-06	.00E+00	.00E+00	2.20E-08	1.90E-08	6.30E-06	5.30E-06
26 BR-83+D	3.87E-06	5.61E-08	.00E+00	.00E+00	9.30E-11	6.40E-11	3.10E-07	1.70E-08
27 BR-84	5.26E-06	4.15E-13	.00E+00	.00E+00	1.40E-08	1.20E-08	5.30E-06	3.50E-06
34 RB-86	1.80E-05	4.27E-06	.00E+00	.00E+00	7.20E-10	6.30E-10	8.50E-07	1.70E-07
35 RB-88	3.26E-05	.00E+00	.00E+00	.00E+00	4.00E-09	3.50E-09	3.60E-06	1.20E-06
36 RB-89	2.88E-06	.00E+00	.00E+00	.00E+00	1.60E-08	1.50E-08	5.80E-06	4.50E-06
37 SR-89	9.13E-06	4.98E-05	.00E+00	3.20E-04	6.50E-13	5.60E-13	5.40E-07	4.60E-09
38 SR-90	8.95E-05	1.23E-04	.00E+00	3.36E-04	.00E+00	.00E+00	1.50E-07	5.40E-10
39 SR-90D	2.65E-10	1.05E-04	.00E+00	9.86E-09	2.60E-12	2.20E-12	9.60E-07	1.30E-06
40 SR-91	2.43E-07	2.87E-05	.00E+00	5.82E-06	8.30E-09	7.10E-09	2.90E-06	1.90E-06
41 SR-92	9.35E-06	4.31E-05	.00E+00	2.16E-06	1.00E-08	9.00E-09	3.10E-06	2.60E-06
42 Y-90	2.65E-10	1.05E-04	.00E+00	9.86E-09	2.60E-12	2.20E-12	9.60E-07	1.30E-06
43 Y-91M	3.48E-12	2.91E-10	.00E+00	8.89E-11	4.40E-09	3.80E-09	1.20E-06	1.00E-06
44 Y-91	3.60E-09	7.50E-05	.00E+00	1.36E-07	2.70E-11	2.40E-11	5.70E-07	6.70E-09
45 Y-92	2.50E-11	1.49E-05	.00E+00	8.57E-10	1.90E-09	1.60E-09	2.00E-06	4.60E-07
46 Y-93	5.53E-11	6.31E-05	.00E+00	1.98E-09	7.80E-10	5.70E-10	1.40E-06	1.90E-07
47 ZR-95	6.34E-09	2.93E-05	.00E+00	2.70E-08	5.80E-09	5.00E-09	1.80E-06	1.50E-06
48 ZR-95D	1.81E-09	2.03E-05	.00E+00	5.56E-08	6.00E-09	5.10E-09	1.60E-06	1.40E-06
49 ZR-97	1.59E-10	1.07E-04	.00E+00	1.69E-09	6.40E-09	5.50E-09	2.40E-06	1.50E-06
50 ZR-97D	4.70E-12	4.09E-08	.00E+00	5.06E-11	5.40E-09	4.60E-09	1.90E-06	1.20E-06
51 NB-95	1.81E-09	2.03E-05	.00E+00	5.56E-09	6.00E-09	5.10E-09	1.60E-06	1.40E-06
52 NB-97	4.70E-12	4.09E-08	.00E+00	5.06E-11	5.40E-09	4.60E-09	1.90E-06	1.20E-06
53 MO-99+D	7.92E-07	9.65E-06	.00E+00	.00E+00	2.20E-09	1.90E-09	9.10E-07	4.70E-07
54 MO-99D	2.01E-08	2.00E-06	.00E+00	1.77E-09	9.50E-10	8.30E-10	2.40E-07	2.10E-07
55 TC-99M	2.01E-08	2.00E-06	.00E+00	1.77E-09	1.10E-09	9.60E-10	2.70E-07	2.40E-07
58 RU-103+D	7.87E-08	2.09E-05	.00E+00	1.72E-07	4.20E-09	3.60E-09	1.10E-06	8.90E-07
59 RU-105+D	6.03E-09	9.19E-06	.00E+00	1.49E-08	5.10E-09	4.50E-09	1.80E-06	1.20E-06
60 RU-106+D	3.56E-07	1.01E-04	.00E+00	2.79E-06	1.80E-09	1.50E-09	1.90E-06	3.60E-07
61 RH-105	5.82E-08	1.36E-05	.00E+00	1.15E-07	7.70E-10	6.60E-10	3.00E-07	1.70E-07
62 PD-109+D	4.16E-08	2.05E-05	.00E+00	.00E+00	4.00E-11	3.50E-11	3.40E-07	9.30E-09
64 AG-111	1.21E-08	4.34E-05	.00E+00	5.74E-08	2.10E-10	1.80E-10	3.80E-07	4.80E-08
68 SB-127	1.18E-07	6.54E-05	4.07E-09	3.57E-07	6.60E-09	5.70E-09	1.80E-06	1.50E-06
69 TE-125M	3.49E-07	1.05E-05	7.94E-07	2.72E-06	4.80E-11	3.50E-11	1.50E-08	3.60E-09
70 TE-127M	7.62E-07	2.10E-05	1.61E-06	6.40E-06	1.30E-12	1.10E-12	1.80E-09	2.60E-10
71 TE-127	2.21E-08	5.13E-06	7.53E-08	1.03E-07	1.10E-11	1.00E-11	1.70E-07	2.80E-09
72 TE-129M+D	1.77E-06	5.79E-05	4.50E-06	1.17E-05	9.00E-10	7.70E-10	7.40E-07	2.10E-07
73 TE-129	7.61E-09	2.12E-08	2.40E-08	3.13E-08	8.40E-10	7.10E-10	7.00E-07	1.90E-07
74 TE-131M	4.71E-07	3.84E-05	6.92E-07	8.02E-07	9.90E-09	8.40E-09	2.70E-06	2.20E-06
75 TE-131	6.25E-09	3.58E-14	1.63E-06	1.95E-08	2.60E-09	2.20E-09	1.60E-06	7.40E-07
76 TE-132	1.54E-06	7.79E-05	1.82E-06	2.56E-06	2.00E-09	1.70E-09	4.80E-07	4.00E-07
77 TE-132D	1.98E-07	1.07E-07	7.33E-05	2.08E-07	2.00E-08	1.70E-08	5.50E-06	4.40E-06
78 TE-133M+D	2.35E-06	1.45E-09	3.52E-08	4.04E-08	1.70E-08	1.50E-08	5.00E-06	3.90E-06
79 TE-134	2.20E-08	4.40E-09	2.85E-08	3.25E-08	1.20E-09	1.00E-09	3.50E-07	2.50E-07
81 I-130	8.77E-07	1.89E-05	2.80E-04	7.44E-07	1.70E-08	1.40E-08	4.80E-06	3.90E-06
82 I-131	3.37E-06	1.53E-06	1.88E-03	3.93E-06	3.40E-09	2.80E-09	9.30E-07	6.80E-07
83 I-132	1.96E-07	1.07E-07	7.33E-05	2.08E-07	2.00E-08	1.70E-08	5.50E-06	4.40E-06
84 I-133	7.62E-07	2.25E-06	4.82E-04	1.43E-06	4.50E-09	3.70E-09	1.50E-06	9.60E-07
85 I-134	1.02E-07	2.25E-10	3.73E-05	1.07E-07	1.90E-08	1.60E-08	5.50E-06	4.20E-06
86 I-135	4.50E-07	1.41E-09	1.76E-04	5.01E-07	1.40E-08	1.20E-08	4.00E-06	3.30E-06
94 CS-134M	2.43E-06	1.63E-09	.00E+00	2.25E-06	7.30E-10	6.20E-10	1.90E-07	1.60E-07
95 CS-134	1.00E-04	2.56E-06	.00E+00	5.29E-05	1.40E-08	1.20E-08	3.50E-06	2.90E-06
97 CS-136	1.81E-05	2.86E-06	.00E+00	6.24E-06	1.70E-08	1.50E-08	4.80E-06	4.10E-06
98 CS-137	5.60E-05	2.05E-06	.00E+00	6.37E-05	4.90E-09	4.20E-09	1.40E-06	1.00E-06
99 CS-138	5.49E-08	4.09E-13	.00E+00	5.66E-08	2.40E-08	2.10E-08	5.70E-06	4.00E-06
100 CS-139	1.97E-08	3.54E-30	.00E+00	3.18E-08	7.20E-09	6.30E-09	3.20E-06	1.70E-06
101 BA-139	2.88E-09	1.88E-07	.00E+00	9.85E-08	2.70E-09	2.40E-09	1.00E-06	7.70E-06
102 BA-140	1.33E-06	4.02E-05	.00E+00	2.02E-05	2.40E-09	2.10E-09	7.60E-07	4.90E-07
103 BA-140D	3.34E-10	9.32E-05	.00E+00	2.53E-09	1.70E-08	1.50E-08	5.30E-06	4.10E-06
106 LA-140	3.34E-10	9.32E-05	.00E+00	2.53E-09	1.70E-08	1.50E-08	5.30E-06	4.10E-06
107 LA-141	2.03E-11	1.24E-05	.00E+00	3.90E-10	2.80E-10	2.50E-10	1.00E-06	5.10E-08
108 LA-142	1.44E-11	4.10E-07	.00E+00	1.29E-10	1.80E-08	1.50E-08	5.90E-06	4.50E-06
109 CE-141	6.88E-10	2.28E-05	.00E+00	8.83E-09	6.20E-10	5.50E-10	2.40E-07	1.30E-07
110 CE-143	1.33E-10	4.39E-05	.00E+00	1.60E-09	2.50E-09	2.20E-09	1.00E-06	5.70E-07
111 CE-144+D	1.98E-08	1.69E-04	.00E+00	3.27E-07	3.70E-10	3.20E-10	1.40E-06	8.60E-08
112 PR-143	4.39E-10	3.86E-05	.00E+00	8.96E-09	.00E+00	.00E+00	2.80E-07	1.60E-09
114 ND-147	4.03E-10	3.34E-05	.00E+00	5.43E-09	1.20E-09	1.00E-09	5.00E-07	2.80E-07
115 PM-147	1.22E-09	7.93E-06	.00E+00	2.36E-08	.00E+00	.00E+00	1.30E-08	7.50E-11
116 PM-148	6.11E-10	9.43E-05	.00E+00	7.29E-09	5.30E-09	4.60E-09	2.00E-06	1.10E-06
117 PM-149	8.64E-11	4.00E-05	.00E+00	1.50E-09	2.90E-11	2.50E-11	3.50E-07	1.50E-08
118 PM-151	6.06E-11	3.35E-05	.00E+00	7.23E-10	2.30E-09	2.20E-09	9.40E-07	5.00E-07

119 SM-153	5.98E-11	2.86E-05	.00E+00	9.86E-10	3.00E-10	2.70E-10	2.50E-07	6.50E-08
120 EU-156	1.69E-09	7.24E-05	.00E+00	1.36E-08	8.70E-09	7.60E-09	2.80E-06	2.10E-06
124 U-237	1.47E-10	1.94E-05	.00E+00	5.53E-10	1.30E-09	1.00E-09	3.40E-07	2.60E-07
125 NP-238	2.11E-10	3.43E-05	.00E+00	4.27E-09	3.20E-09	2.80E-09	1.10E-06	7.70E-07
126 NP-239	6.46E-11	2.40E-05	.00E+00	1.20E-09	1.10E-09	9.50E-10	3.70E-07	2.40E-07
130 PU-241+D	4.21E-10	6.78E-07	.00E+00	1.44E-08	6.80E-12	4.60E-12	9.50E-11	6.10E-11

CASE 1: SAMPLE ARRRG RUN 01/14/74

ISOTOPES CONTRIBUTING AT LEAST 4% TO DOSE

	--T O T A L B O D Y--			-----G I - L L I------			----T H Y R O I D-----			--------B O N E--------		
FISH	CS-134	1.06E-02	64%	H-3	6.22E-05	5%	I-131	6.58E-02	87%	CS-134	5.58E-03	47%
	CS-137	5.12E-03	31%	TE-129M	9.07E-05	6%	I-133	8.68E-03	12%	CS-137	5.82E-03	49%
				TE-132	5.75E-04	38%						
				CS-134	2.70E-04	18%						
				CS-136	6.97E-05	5%						
				CS-137	1.87E-04	12%						
TOTALS	BODY	1.64E-02		GI-LLI	1.51E-03		THYROID	7.56E-02		BONE	1.18E-02	
DRINKING WATER	H-3	7.72E-03	91%	H-3	3.89E-03	88%	I-131	1.97E-01	85%	I-131	3.94E-04	54%
	I-131	3.38E-04	4%				I-133	2.52E-02	11%	I-133	7.48E-05	10%
										CS-134	1.19E-04	16%
										CS-137	1.24E-04	17%
TOTALS	BODY	8.45E-03		GI-LLI	4.42E-03		THYROID	2.20E-01		BONE	7.29E-04	

	-------S K I N--------			--T O T A L B O D Y--		
SHORELINE	CS-134	4.07E-04	29%	CS-134	3.49E-04	29%
	CS-137	9.04E-04	64%	CS-137	7.74E-04	64%
TOTALS	SKIN	1.40E-03		BODY	1.20E-03	
SWIMMING	I-131	1.36E-04	26%	I-131	9.92E-05	27%
	I-132	2.12E-05	4%	I-132	1.69E-05	5%
	I-133	1.99E-04	39%	I-133	1.28E-04	35%
	I-135	1.03E-04	20%	I-135	8.46E-05	23%
TOTALS	SKIN	5.15E-04		BODY	3.68E-04	
BOATING	SAME AS SWIMMING					
TOTALS	SKIN	2.57E-04		BODY	1.84E-04	

CASE 1: SAMPLE ARRRG RUN 01/14/74

	HOLDUP TIME HOURS	USAGE PER YR	MIXING RATIO
FISH	24	33.6	.03
DRINKING WATER	24	1430	.03
SHORELINE	5	106	.14
SWIMMING	5	416	.14
BOATING	5	416	.14

PLANT LIFE= 30 YEARS SHORE WIDTH FACTOR= .5

RECONCENTRATION FORMULA NUMBER 3

COOLANT FLOW TO PLANT = 790 CUBIC FEET/SEC = 7.06E+11 LITERS/YEAR

---------DOSE TO INDIVIDUAL, MREM/YEAR---------

	SKIN	BODY	GI-LLI	THYROID	BONE
FISH		1.64E-02	1.51E-03	7.56E-02	1.18E-02
DRINKING WATER		8.45E-03	4.42E-03	2.20E-01	7.29E-04
SHORELINE	1.40E-03	1.20E-03	1.20E-03	1.20E-03	1.20E-03
SWIMMING	5.15E-04	3.68E-04	3.68E-04	3.68E-04	3.68E-04
BOATING	2.57E-04	1.84E-04	1.84E-04	1.84E-04	1.84E-04
TOTALS	2.18E-03	2.66E-02	7.69E-03	2.97E-01	1.43E-02

SUMMARY OF RUN PIKES PEAK

CASE 1: SAMPLE ARRRG RUN

ARRRG ** ARRRG ** ARRRG ** ARRRG ** ARRRG 01/14/74 12:54 ARRRG ** ARRRG ** ARRRG ** ARRRG ** ARRRG

MAIL TO: NM ROBINSON, 3717 BLDG, 300 AREA, RICHLAND, WASHINGTON 99352

CRITR obtains its input from three sources:

(1) The reactor coolant flow, reconcentration parameters, holdup, mixing ratio and information characterizing each organism are entered by the user at the time of the run. Section III-A.7.5 discusses the choice of parameters to use for the reconcentration factor and mixing ratios. The standard input to be used for the other parameters in absence of information specific to the site is given in Table III-A-9.

(2) The reactor release rate file REL is shared by ARRRG and CRITR. The discussion of REL in Section III-A.7.2 also applies to CRITR.

(3) The file ARGIN is also shared by ARRRG and CRITR, and the discussion of ARGIN in Section III-A.7.2 also applies to CRITR. The file CRITEN Table III-A-18 contains a tabulation by nuclide of effective energy per disintegration for seven critter* radii between 1.4 cm and 20 cm and for the total body of man.

Table III-A-19 shows teletype printout for a typical run, with user input indicated by wavy underlines. The reactor name determines which set of releases from REL will be accessed by the program. A title is entered to identify the teletype printout, but is not otherwise used by the program. Holdup time in hours, mixing ratio and effective critter radius in cm, is then entered for the primary critter. The program summarizes the input for the user to check, and if the response to "constant OK?" is N or NO, the user is given a chance to re-enter the parameters. CRITR then calculates and prints the internal dose to the four primary organisms of the given radius: fish, crustacea, molluscs and algae.

Any name is allowed for the secondary critter. The holdup time, mixing ratio and the radius are entered. The tabulated radius in CRITEN closest to the user-specified radius is used to scale this dose factor to the size of the organism. The food type may be specified using any of the following names:

Response to "food type?"	Organism Used for Dose Calculation
fish	fish
crustacea, shellfish, lobsters	crustacea
molluscs, oysters, clams	molluscs
algae, plants	algae

The program examines only the first two letters of "food type" so the operator need not be concerned whether his response is singular or plural, or is a variant spelling. After entering the food intake rate and mass, the user is given a chance to examine and reject the parameters. CRITR uses the adult whole body ingestion dose factors to calculate internal doses, then calculates and prints the internal dose for the secondary critter.

By answering Y or YES to "another secondary critter?" the user may repeat the secondary critter portion of the calculation, up to a maximum of six secondary critters. At user option, a table of percent contribution to each internal dose by nuclide is printed for each nuclide contributing at least a user-specified minimum percent. The release, recirculation factor, concentration, bioaccumulation factor, body burden, dose and percent contribution are printed for each nuclide. Also at user option, a list of releases and water concentrations is printed for all nuclides.

III-A.7.4 Program GRONK

GRONK (Gas Release of.NuKlides) calculates annual dose resulting from radionuclide releases in gaseous effluents, using Equations 8 and 9. Skin and whole body dose to an individual and total-body dose to the population are calculated in 16 sectors and in up to 10 annular rings out to 50 miles from the point of release. An optional calculation is the thyroid dose via the inhalation, milk and leafy vegetable pathways at a user-specified set of ranges.

Meteorology is accepted in either the Pasquill or Hanford format. The user may specify the release height of the effluents, a plume rise constant, a building-wake correction and a meteorology height correction. If the optional thyroid dose calculation is selected, the user may specify a grazing period, vegetable consumption period and the vegetable consumption rate.

A detailed output is automatically sent to a high-speed printer. This output contains:

- the population table supplied by the user
- meteorology tables supplied by the user

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* In CRITR jargon, "critter" means "organism."

9 1 1 1 3 9 1 1 4 3 4

TABLE III-A-18

FILE CRITEN

1 FILE FOR CRITR. ENERGIES (MEV) FOR VARIOUS EFFECTIVE RADII OF MUSCLE

2	ISO	1.4 CM	2 CM	3 CM	5 CM	7 CM	10 CM	20 CM	MAN
10	H-3	.0058	.0058	.0058	.0058	.0058	.0058	.0058	.01
20	C-14	.05	.05	.05	.05	.05	.05	.05	.05
30	N-13	.538	.557	.587	.646	.701	.777	.983	1.13
40	F-18	.285	.304	.334	.391	.444	.518	.717	.861
50	NA-22	.286	.325	.387	.507	.619	.775	1.20	1.51
60	NA-24	.712	.771	.868	1.05	1.23	1.48	2.19	2.74
70	P-32	.695	.695	.695	.695	.695	.695	.695	.695
80	AR-39	.194	.194	.194	.194	.194	.194	.194	.194
90	AR-41	.519	.541	.576	.642	.705	.793	1.04	1.22
100	SC-46	.197	.232	.290	.399	.501	.644	1.03	1.32
110	CR-51	.00222	.00276	.00363	.00529	.00685	.00901	.0149	.0191
120	MN-54	.0364	.0514	.0758	.122	.166	.227	.392	.512
130	MN-56	.875	.904	.951	1.04	1.13	1.24	1.57	1.82
140	FE-55	.00726	.00726	.00726	.00726	.00726	.00726	.00726	.00726
150	FE-59	.171	.191	.224	.286	.346	.428	.655	.824
160	CO-57	.0390	.0409	.0439	.0496	.0550	.0626	.0840	.100
170	CO-58	.0728	.0905	.119	.174	.226	.297	.492	.633
180	CO-60	.195	.237	.306	.437	.560	.732	1.21	1.56
190	NI-63	.0176	.0176	.0176	.0176	.0176	.0176	.0176	.0176
200	NI-65	.641	.651	.666	.695	.723	.762	.869	.949
210	CU-64	.133	.137	.143	.154	.165	.180	.220	.249
220	ZN-65	.0289	.0386	.0544	.0846	.113	.153	.261	.342
230	ZN-69M+D	.0400	.0477	.0603	.0842	.107	.138	.221	.282
240	ZN-69	.32	.32	.32	.32	.32	.32	.32	.32
250	BR-82	.248	.294	.368	.510	.643	.828	1.33	1.70
260	KR-83+D	.363	.363	.364	.364	.364	.365	.366	.367
270	BR-84	1.31	1.34	1.39	1.47	1.56	1.67	2.00	2.25
280	BR-85	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
290	KR-83M	.0438	.0438	.0438	.0438	.0438	.0438	.0438	.0438
300	KR-85M	.245	.248	.252	.260	.268	.279	.309	.331
310	KR-85	.224	.224	.224	.224	.224	.225	.225	.225
320	KR-87	1.21	1.24	1.27	1.34	1.41	1.50	1.77	1.97
330	KR-88	.449	.475	.517	.599	.677	.786	1.09	1.33
340	RB-86	.666	.666	.671	.676	.680	.687	.705	.719
350	RB-88	2.15	2.16	2.18	2.21	2.24	2.28	2.40	2.49
360	RB-89	.694	.733	.797	.919	1.03	1.20	1.64	1.98
370	SR-89	.564	.564	.564	.564	.564	.564	.564	.564
380	SR-90	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14
390	SR-90D	.939	.939	.939	.939	.939	.939	.939	.939
400	SR-91	.702	.721	.752	.812	.867	.944	1.15	1.31
410	SR-92	.249	.272	.310	.381	.449	.543	.805	1.00
420	Y-90	.939	.939	.939	.939	.939	.939	.939	.939
430	Y-91M	.0518	.0615	.0773	.107	.135	.174	.280	.355
440	Y-91	.590	.590	.591	.591	.591	.591	.592	.592
450	Y-92	1.47	1.47	1.48	1.49	1.51	1.52	1.57	1.61
460	Y-93	1.18	1.18	1.18	1.19	1.19	1.20	1.22	1.23
470	ZR-95	.227	.254	.297	.380	.458	.565	.857	1.07
480	ZR-95D	.0767	.0906	.113	.156	.197	.253	.405	.515
490	ZR-97	.763	.778	.802	.848	.891	.951	1.11	1.23
500	ZR-97D	.500	.512	.532	.570	.606	.656	.790	.887
510	NB-95	.0767	.0906	.113	.156	.197	.253	.405	.515
520	NB-97	.500	.512	.532	.570	.606	.656	.790	.887
530	MO-99+D	.419	.423	.430	.444	.457	.475	.524	.561
540	MO-99D	.084	.084	.084	.084	.084	.084	.084	.084
550	TC-99M	.132	.134	.138	.144	.150	.158	.181	.199
560	TC-99	.084	.084	.084	.084	.084	.084	.084	.084
570	TC-101	.485	.492	.503	.524	.543	.570	.643	.697
580	RU-103+D	.116	.125	.140	.168	.194	.230	.328	.399
590	RU-105+D	.496	.508	.527	.563	.597	.644	.772	.865
600	RU-106+D	1.44	1.44	1.45	1.46	1.47	1.49	1.53	1.56
610	RH-105	.158	.159	.162	.167	.172	.179	.198	.212
620	PD-109+D	.389	.389	.389	.389	.389	.390	.390	.391
630	AG-110M+D	.188	.235	.311	.456	.593	.782	1.30	1.68
640	AG-111	.361	.362	.362	.364	.365	.367	.372	.376
650	SN-125	.906	.907	.910	.914	.919	.925	.942	.954
660	SB-124	.459	.491	.544	.644	.739	.871	1.24	1.51
670	SB-125	.105	.113	.126	.150	.173	.205	.291	.353
680	SB-127	.433	.446	.472	.518	.561	.620	.782	.899
690	TE-125M	.111	.111	.112	.112	.112	.113	.113	.114
700	TE-127M	.00197	.00197	.00197	.00198	.00199	.00200	.00203	.00205
710	TE-127	.223	.223	.223	.223	.223	.224	.224	.224
720	TE-129M+D	.599	.601	.605	.612	.619	.627	.651	.667
730	TE-129	.535	.538	.541	.548	.555	.563	.585	.601
740	TE-131M	.269	.291	.327	.396	.460	.550	.796	.978
750	TE-131	.786	.791	.800	.817	.833	.855	.916	.961
760	TE-132	.121	.125	.131	.143	.154	.169	.211	.242
770	TE-132D	.581	.624	.693	.826	.950	1.12	1.59	1.94
780	TE-133M+D	.502	.542	.605	.726	.840	.998	1.43	1.74
790	TE-134	.114	.117	.122	.130	.138	.148	.175	.194
800	I-129	.0474	.0475	.0476	.0478	.0479	.0481	.0485	.0487
810	I-130	.388	.427	.490	.611	.724	.881	1.31	1.61
820	I-131	.206	.213	.224	.245	.266	.293	.368	.422
830	I-132	.581	.624	.693	.826	.950	1.12	1.59	1.94
840	I-133	.467	.478	.497	.533	.566	.613	.738	.829
850	I-134	.779	.838	.934	1.12	1.29	1.53	2.19	2.67
860	I-135	.481	.514	.566	.667	.761	.893	1.26	1.53
870	XE-131M	.136	.136	.136	.137	.137	.137	.138	.139
880	XE-133M	.176	.177	.178	.180	.182	.184	.191	.196
890	XE-133	.137	.137	.138	.140	.141	.143	.148	.152
900	XE-135M	.118	.126	.139	.163	.186	.217	.302	.363
910	XE-135	.330	.335	.342	.355	.368	.386	.434	.469
920	XE-137	1.66	1.68	1.68	1.69	1.70	1.71	1.74	1.76
930	XE-138	.505	.527	.562	.630	.694	.784	1.04	1.23
940	CS-134M	.0483	.0496	.0517	.0558	.0597	.0652	.0805	.0922
950	CS-134	.230	.259	.306	.396	.480	.596	.913	1.14
960	CS-135	.058	.058	.058	.058	.058	.058	.058	.058
970	CS-136	.233	.273	.337	.458	.573	.732	1.17	1.49
980	CS-137	.257	.267	.284	.316	.346	.388	.500	.582
990	CS-138	1.18	1.22	1.27	1.38	1.48	1.62	2.02	2.32
1000	CS-139	1.61	1.61	1.62	1.64	1.66	1.68	1.75	1.79
1010	BA-139	.927	.927	.929	.931	.933	.936	.944	.950
1020	BA-140	.315	.320	.328	.343	.357	.376	.428	.465
1030	BA-140D	.698	.734	.793	.907	1.01	1.16	1.58	1.89
1040	BA-141	1.10	1.11	1.12	1.16	1.19	1.23	1.36	1.44
1050	BA-142	.601	.622	.656	.722	.783	.869	1.10	1.28
1060	LA-140	.698	.734	.793	.907	1.01	1.16	1.58	1.89
1070	LA-141	.966	.967	.967	.969	.970	.972	.977	.981
1080	LA-142	.937	.973	1.03	1.14	1.25	1.40	1.82	2.14
1090	CE-141	.173	.174	.175	.179	.182	.187	.199	.209
1100	CE-143	.420	.426	.435	.453	.470	.493	.555	.601
1110	CE-144+D	1.32	1.32	1.32	1.33	1.33	1.33	1.34	1.35
1120	PR-143	.314	.314	.314	.314	.314	.314	.314	.314
1130	PR-144	1.23	1.23	1.23	1.24	1.24	1.24	1.24	1.25
1140	ND-147	.257	.259	.264	.272	.280	.291	.320	.342
1150	PM-147	.0620	.0620	.0620	.0620	.0620	.0620	.0620	.0620
1160	PM-148	.727	.737	.755	.788	.819	.862	.982	1.07
1170	PM-149	.366	.367	.367	.367	.368	.368	.370	.371
1180	PM-151	.327	.332	.340	.356	.370	.390	.445	.484
1190	SM-153	.270	.271	.272	.273	.275	.277	.283	.288
1200	EU-156	.471	.490	.521	.580	.636	.714	.930	1.09
1210	W-181	.00316	.00316	.00317	.00318	.00320	.00322	.00327	.00331
1220	W-185	.144	.144	.144	.144	.144	.144	.144	.144
1230	W-187	.331	.339	.353	.379	.403	.437	.529	.595
1240	U-237	.142	.146	.151	.158	.165	.174	.200	.223
1250	NP-238	.263	.270	.282	.306	.327	.357	.440	.513
1260	NP-239	.203	.205	.208	.212	.217	.223	.240	.260
1270	PU-238	5.51	5.51	5.51	5.51	5.51	5.51	5.51	55.0
1280	PU-239	5.15	5.15	5.15	5.15	5.15	5.15	5.15	51.5
1290	PU-240	5.16	5.16	5.16	5.16	5.16	5.16	5.16	51.6
1300	PU241+D	.00535	.00535	.00535	.00535	.00535	.00535	.00535	.00636
1310	PU-242	4.90	4.90	4.90	4.90	4.90	4.90	4.90	48.9
1320	AM-241	5.51	5.51	5.51	5.52	5.52	5.52	5.52	54.8
1330	AM-243+D	5.28	5.28	5.28	5.29	5.29	5.29	5.30	52.7
1340	CM-242	6.11	6.11	6.11	6.11	6.11	6.11	6.11	61.1
1350	CM-244	5.80	5.80	5.80	5.80	5.80	5.80	5.80	58.0
1360	CF-252	12.2	12.2	12.2	12.2	12.2	12.2	12.2	165.

TABLE III-A-19

TELETYPE PRINTOUT FOR SAMPLE CRITR RUN

```
RUN CRITR

CRITR   13:30   01/14/74

REACTOR NAME?PIKES PEAK

TITLE?SAMPLE CRITR RUN

ENTER COOLING FLOW IN CFS?800
WHICH RECONCENTRATION FORMULA?3

FOR PRIMARY CRITTER * * * *

ENTER HOLDUP TIME IN HOURS & MIXING RATIO?0 1
ENTER CRITTER RADIUS IN CM. ?2

PIKES PEAK     FLOW: 800      CONSTANT RECONC:1

HOLDUP: 0      MIXING RATIO: 1      RADIUS: 2

CONSTANTS OK?YES

FISH INTERNAL DOSE :        4.5 MRAD/YR

CRUSTACEA INTERNAL DOSE : 1.84 MRAD/YR

MOLLUSC INTERNAL DOSE :   1.84 MRAD/YR

ALGAE INTERNAL DOSE :     7.17 MRAD/YR


FOR SECONDARY CRITTER * * * *

NAME OF CRITTER?HERON
ENTER HOLDUP TIME IN HOURS & MIXING RATIO?0 1
ENTER CRITTER RADIUS IN CM. ?7
ENTER FOOD TYPE?FISH
ENTER FOOD INTAKE RATE IN GRAMS/DAY?600
ENTER CRITTER MASS IN KG?4.6

HOLDUP : 0      MIXING RATIO : 1

FOOD TYPE :FISH     INTAKE RATE : 600

RADIUS: 7     MASS: 4.6       CONSTANTS OK?Y

INTERNAL DOSE FOR HERON :  25.6827  MRAD/YR

ANOTHER SECONDARY CRITTER?N

PERCENTAGES?Y
MINIMUM ??5

     * * *  CONTRIBUTIONS TO CRITTER DOSE > 5 %  * * *
```

ISOTOPE	RELEASE CI/YR	RECONC. FACTOR	CONC. PCI/L	BIOACCUM. FACTOR	BODY BUR. PCI/KG	DOSE MRAD/YR	PERCENT
FISH							
RB-88	2.10E-02	1.00	2.9E-02	2000	5.9E+01	2.4E+00	52.7
I-133	1.90E+00	1.00	2.7E+00	15	4.0E+01	3.6E-01	7.9
CS-134	3.70E-02	1.00	5.2E-02	2000	1.0E+02	5.0E-01	11.1
CS-137	3.20E-02	1.00	4.5E-02	2000	9.0E+01	4.5E-01	9.9
CRUSTACEA							
H-3	1.00E+03	1.00	1.4E+03	1	1.3E+03	1.4E-01	7.4
RB-88	2.10E-02	1.00	2.9E-02	1000	2.9E+01	1.2E+00	64.5
I-133	1.90E+00	1.00	2.7E+00	5	1.3E+01	1.2E-01	6.5
MOLLUSC							
H-3	1.00E+03	1.00	1.4E+03	1	1.3E+03	1.4E-01	7.4
RB-88	2.10E-02	1.00	2.9E-02	1000	2.9E+01	1.2E+00	64.5
I-133	1.90E+00	1.00	2.7E+00	5	1.3E+01	1.2E-01	6.5
ALGAE							
RB-88	2.10E-02	1.00	2.9E-02	1000	2.9E+01	1.2E+00	16.5
MO-99+D	2.60E-01	1.00	3.6E-01	1000	3.6E+02	2.9E+00	40.1
MO-99D	2.30E-01	1.00	3.2E-01	1000	3.2E+02	5.1E-01	7.0
I-131	1.80E+00	1.00	2.5E+00	40	1.0E+02	4.0E-01	5.6
I-133	1.90E+00	1.00	2.7E+00	40	1.1E+02	9.5E-01	13.3
HERON							
CS-134	3.70E-02	1.00	5.2E-02	2000	1.6E+03	1.4E+01	56.4
CS-137	3.20E-02	1.00	4.5E-02	2000	1.5E+03	9.9E+00	38.6

```
DO YOU WANT TOTAL LIST OF RELEASES?Y
```

ISOTOPE	RELEASE CI/YR	CONCENTRATION PCI/LITER
H-3	1.00E+03	1.40E+03
CR-51	5.70E-04	7.97E-04
MN-54	6.10E-04	8.53E-04
FE-55	1.30E-03	1.82E-03
FE-59	6.60E-04	9.23E-04
CO-58	6.90E-03	9.65E-03
CO-60	5.60E-04	7.83E-04
BR-82	9.60E-04	1.34E-03
BR-83+D	3.40E-03	4.76E-03
RB-84	4.90E-05	6.85E-05
RB-86	6.20E-05	8.67E-05
RB-88	2.10E-02	2.94E-02
RB-89	1.10E-05	1.54E-05
SR-89	3.60E-04	5.04E-04
SR-90	1.30E-05	1.82E-05
SR-90D	1.30E-05	1.82E-05
SR-91	2.40E-04	3.36E-04
SR-92	1.10E-05	1.54E-05
Y-90	1.90E-05	2.66E-05
Y-91M	1.50E-04	2.10E-04
Y-91	3.40E-03	4.76E-03
Y-92	4.10E-05	5.73E-05
Y-93	4.30E-05	6.01E-05
ZR-95	6.00E-05	8.39E-05
ZR-95D	6.00E-05	8.39E-05
ZR-97	1.70E-05	2.38E-05
ZR-97D	1.70E-05	2.38E-05
NB-95	6.30E-05	8.81E-05
NB-97	1.80E-05	2.52E-05
MO-99+D	2.60E-01	3.64E-01
MO-99D	2.30E-01	3.20E-01
TC-99M	2.10E-01	2.94E-01
RU-103+D	4.00E-05	5.59E-05
RU-105+D	5.80E-06	8.11E-06
RU-106+D	1.30E-05	1.82E-05
RH-105	1.50E-05	2.10E-05
PD-109+D	1.40E-06	1.96E-06
AG-111	7.00E-07	9.79E-07
SB-127	1.40E-06	1.96E-06
TE-125M	3.30E-05	4.62E-05
TE-127M	2.90E-04	4.06E-04
TE-127	2.90E-04	4.06E-04
TE-129M+D	2.80E-03	3.92E-03
TE-129	1.80E-03	2.52E-03
TE-131M	1.20E-03	1.68E-03
TE-131	2.40E-04	3.36E-04
TE-132	1.60E-02	2.24E-02
TE-132D	1.60E-02	2.24E-02
TE-133M+D	7.80E-06	1.09E-05
TE-134	6.30E-06	8.81E-06
I-130	6.20E-03	8.67E-03
I-131	1.80E+00	2.52E+00
I-132	2.10E-01	2.94E-01
I-133	1.90E+00	2.66E+00
I-134	2.00E-03	2.80E-03
I-135	5.20E-01	7.27E-01
CS-134M	1.40E-05	1.96E-05
CS-134	3.70E-02	5.18E-02
CS-136	9.00E-03	1.26E-02
CS-137	3.20E-02	4.48E-02
CS-138	1.50E-04	2.10E-04
CS-139	5.10E-06	7.13E-06
BA-139	1.50E-04	2.10E-04
BA-140	3.30E-04	4.62E-04
BA-140D	3.30E-04	4.62E-04
LA-140	2.00E-04	2.80E-04
LA-141	3.30E-05	4.62E-05
LA-142	7.10E-07	9.93E-07
CE-141	6.00E-05	8.39E-05
CE-143	2.50E-05	3.50E-05
CE-144+D	5.10E-05	7.13E-05
PR-143	4.40E-05	6.15E-05
ND-147	1.80E-05	2.52E-05
PM-147	2.90E-06	4.06E-06
PM-148	6.50E-06	9.09E-06
PM-149	8.80E-06	1.23E-05
PM-151	2.50E-06	3.50E-06
SM-153	4.60E-06	6.43E-06
EU-156	2.30E-06	3.22E-06
U-237	1.10E-05	1.54E-05
NP-238	2.40E-06	3.36E-06
NP-239	3.40E-04	4.76E-04
PU-241+D	1.80E-06	2.52E-06

```
          DON'T SUPPORT EXTERNAL DOSES

           THANK YOU ----- CALL AGAIN

NOW AT END
SRU'S:4.6
READY
```

- the meteorology tables after any normalization is performed by the program
- the releases, decay constants and dose factors used by the program
- the percent contribution by nuclide to dose at the point of release (termed "at the stack" in the printout)
- a table of computed $\bar{\chi}/Q'$
- tables of skin and whole body dose to individual and whole body dose to population
- average dose to population in annular rings
- tables of thyroid dose if that option has been selected.

At the time of the run, the user may request that any combination of these tables also be printed at his conversational terminal.

GRONK obtains its data from three sources:

(1) The user specifies at the time of the run the items indicated in Table III-A-20. Due to the large number of possible user options GRONK does not operate in a question-and-answer mode as do ARRRG and CRITR. Instead, at the beginning of the case the user enters letters representing his chosen options. If any of the selected options require user-specified parameters, GRONK will request only those parameters required.

(2) A single file contains all the information necessary to characterize a facility for GRONK. This file named Gxxxx, where xxxx stands for the first four letters of the facility name, is the only file ever modified by the user of GRONK. The information for a given reactor is stored once in Gxxxx at the time the information is received from the applicant. The program automatically accesses the Gxxxx file indicated by the reactor name entered by the user at the time the run is made. Gxxxx contains the radionuclide release rates, population distribution out to 50 miles in 16 sectors and up to 10 annular rings, meteorological data in tables of joint frequency of occurrence of wind speed, direction and stability condition, and certain miscellaneous

TABLE III-A-20

GRONK INPUT WORKSHEET

REACTOR NAME: ____________

RELEASE LIST NAME: ____________ (if more than one set of release rates)

COMMENTS: ____________

MODEL: ☐ PASQUILL MODEL H☐ HANFORD MODEL

RELEASE HEIGHT: ☐ SAME AS PREVIOUS CASE (=0 if case #1) G☐ GROUND RELEASE L☐ ELEVATED RELEASE height= ____

EXTERNAL RANGES: ☐ BUILT-IN RANGES R☐ NEW RANGES (miles): ____ S☐ SAME AS PREVIOUS CASE

PLUME RISE: ☐ SAME AS PREVIOUS CASE (=0 if case #1) P☐ PLUME RISE CONSTANT= ____ meter^2/second

WAKE FACTOR: W☐ USE BUILDING WAKE FACTOR

WIND SPEED: M☐ USE METEOROLOGY HEIGHT CORRECTION

THYROID: T☐ ALSO CALCULATE THYROID DOSES
- GRAZING PERIOD ____ month/year
- VEGETABLE CONSUMPTION PERIOD ____ month/year
- CHILD VEGETABLE CONSUMPTION ____ kilogram/year
- ADULT VEGETABLE CONSUMPTION ____ kilogram/year
- NEW RANGES (miles): ____ or same as external ranges ("escape" key)

ADD TABLES: A☐ ADD SUCCESSIVE CASES (Use for all except last case in group)

PRINTING TABLES AT TELETYPE:
- 0☐ Print population table at teletype
- 1☐ Print raw meteorology tables at teletype
- 2☐ Print derived meteorology tables at teletype
- 3☐ Print releases, decay constants and dose factors at teletype
- 4☐ Print percent by nuclide at teletype
- 5☐ Print χ/Q table at teletype
- 6☐ Print individual skin dose table at teletype
- 7☐ Print individual total body dose table at teletype
- 8☐ Print population total body dose table at teletype
- 9☐ Print thyroid dose tables at teletype
- X☐ Print average population dose table at teletype

For additional cases, fill out another sheet or list differences below:

FOR OPERATOR'S USE:

Option words: #1 ____ #2 ____ #3 ____ #4 ____ #5 ____

Final options: E☐ END RUN F☐ END RUN, THEN OFF N☐ END RUN, THEN RERUN GRONK FOR A NEW REACTOR input. The stability classifications may be of the Pasquill or Hanford model, or both models may be entered for use in separate runs. Detailed rules for the formation of file Gxxxx are given in Table III-A-21.

(3) The 136 nuclide names, decay constants, whole body and skin dose factors, and thyroid dose factors required by GRONK are stored in the permanent file GIN. A table of Pasquill σ_Z versus range by stability condition is stored in the permanent file TONIC (Table III-A-22). In the past some applicants have specified nonstandard Pasquill conditions G and G+; here the σ_Z for these conditions is to be 0.6 times the σ_Z for condition F. GRONK uses linear interpolation for ranges which fall between the tabulated ranges in TONIC.

Table III-A-23 shows the teletype printout for a typical run, with user input indicated by wavy underlines. A worksheet such as that in Table III-A-20 is essential in preparing the input and should be referred to during the following discussion of input to GRONK.

The reactor name determines which reactor data file will be accessed by the program. The option word is a combination of letters which tells GRONK the features that the user desires in the calculation. The letters may be entered in any order and spaces are allowed. The user may select one option from each of the following categories:

Meteorology Model

- Option H: use Hanford Meteorology tables.
- Option H not selected: use Pasquill meteorology tables.

Release Height

- Option G: the effluents are released from ground level.
- Option L: GRONK will later ask for the release height desired by the user. Sample responses are 100F to represent 100 ft or 70M to represent 70 meters.
- Neither options G nor L selected: the release height will be the same as that used in the previous case [it will be assumed equal to zero (ground level release) if this selection is made for the first case].

External Ranges

- Option R: the user will be asked later to enter the ranges for which $\bar{\chi}/Q'$ and skin and whole body dose to individual will be calculated. If this option is selected, GRONK will not have the information necessary to calculate whole body dose to population.
- Option S: the ranges for skin and whole body calculations will be the same as those used in the previous case (built-in ranges will be assumed if this selection is made for the first case).
- Neither options R nor S selected: the "built-in" ranges specified for the population table in paragraph 4 of Table III-A-21 will be used for skin and whole body calculation. Whole body dose to population will be calculated.

Plume Rise

- Option P: the release height h in Equation 9 is replaced by $h + \dfrac{\text{plume rise constant (meter}^2\text{/sec)}}{\bar{u}_j}$ (Reference 15).
- Option P not selected: the plume rise constant will be the same as that used in the previous case (it will be assumed equal to zero if this selection is made for the first case).

TABLE III-A-21

RULES FOR FORMATION FOR FILE GXXXX

Before running GRONK for a new facility, you must create a master file containing the permanent data GRONK will need for that facility. The file shall contain the following data in order.

1. The facility name optionally followed by comments, all on a single line. This line is printed as part of the heading on the first page and on the top of each result page. The total length of this line cannot exceed 72 characters.

2. For each release list:

   a. The word RELEASE, followed by the release list title (enclose title in quotes if more than one word). These items are optional if there is only one release list.

   b. The 136 releases for the facility in Ci/yr in the nuclide order given in Table III-A-14. Use as many lines as you need. Nuclides which are not released must be listed as zero, but the program accepts the shorthand notation rZ to represent r consecutive zero releases. (This notation is not allowed anywhere else in the file.)

3. The word RANGES.

4. The ranges in miles for which the data in the population table are tabulated. Up to ten ranges are allowed.

5. A blank line of at least one space.

6. A line containing:

   a. The word POPULATION.

   b. The date of the population table. If the date is not known, use two adjacent quotation marks. If more than one word is needed to characterize the date of the population table, enclose the words in quotation marks (example: "1970 seasonal").

   c. The name of the sector direction which begins the population table (but see step 18).

7. The population table. Enter the numbers in the same order that GRONK prints them. Use as many lines as you need. The first sector direction must be the same one you specified in step 6, and the sectors must follow in clockwise order.

8. A line containing:

   a. The name of the model (HANFORD or PASQUILL).

   b. The number of sectors in the meteorology tables (only allowed value is 16).

   c. The name of the sector direction which begins the meteorology tables (but see step 18).

   d. The wind-sensor height in meters to use in the wind-speed correction formula. Enter zero if you do not know the height; this will cause building-wake correction requests to be ignored.

   e. The building height in meters to use in the building-wake correction formula. Enter zero if you do not know the height; this will cause wind-speed correction requests to be ignored.

9. The average speed in mph for each column in the meteorology table. A maximum of ten speed categories are allowed.

10. A blank line of at least one space.

11. The column heading (maximum five characters each) to appear in the printout for each speed column of the meteorology table.

12. For each stability condition, the following information:

    a. An abbreviation for the name of the stability condition (quote marks required if more than one word).

b. If the meteorology table is given in percent of all occurrences across all stability conditions, enter the number 100.

If the meteorology table is given in number of observations, enter the total number of observations for all conditions combined. If the total number of observations is not known, enter the number zero. The program will automatically sum and print the total number of observations, and you should then use this number to change Gxxxx before the next run. When zero is used, the "standard form" meteorology output is supressed.

If the meteorology data for each stability condition table sums to 100%: enter the percentage of time that the given stability condition occurs.

c. The percentage (or number) of times the wind direction is listed as variable for each speed interval; use zeroes if not listed. Each value will be distributed equally among all directions in its speed interval.

d. The percentage (or number) of times the wind is listed as calm; use zero if not listed. This value will be distributed equally among all directions in the lowest speed interval.

e. The meteorology table for the given stability condition. Enter the numbers in the same order that GRONK prints them. Use as many lines as you need. The first sector direction must be the same one you specified in step 8c, and the sectors must follow in clockwise order.[a]

13. For the Hanford model, the stability conditions must be in the order: very stable, moderately stable, neutral and unstable. For the Pasquill model, the stability conditions must be in the order: A, B, C, D, E, F, G (optional), and G+ (optional). Both Hanford and Pasquill model meteorology (steps 8 to 12) may be listed for the same reactor, but the Hanford model must be first.

14. (Optional) The word NOTES, followed by as many lines of descriptive comments as you require.

15. The name of the master file containing the data will be G + the first four letters of the reactor name. Example: The Aquirre reactor data is stored on file GAGUI.

16. Naming directions: Direction names in GRONK are the 16 primary compass directions (N, NNE, NE, ENE, etc.), and the 16 directions midway between them (N-NNE, NNE-NE, NE-ENE, etc.).

17. Naming sectors: All sectors are named for the direction of the center of the sector. Examples: if the sector boundaries are NW and NNW, the sector name is NW-NNW. If the sector boundaries are NE-ENE and ENE-E, the sector name is ENE.

18. Agreement Between Population and Meteorology Sectors

- Any desired sector may be chosen to begin the meteorology tables;[a] that same starting sector must be used for every stability condition.
- If the population sectors are offset one-half sector from the meteorology sectors, then for population dose computations the population is adjusted by averaging adjacent sectors. The sector chosen to begin the population table must be one of the two closest to the sector which begins the meteorology tables.
- If there is no offset between population and meteorology sectors, then the same sector must begin the population and meteorology tables.

Example: if the first meteorology sector is N (S in meteorologist's terminology), allowed first population sectors are either NNW-N, N or N-NNE.

(a) The directions used by GRONK are the directions of the people receiving dose (the directions towards which the wind blows). Since meteorology tables received from applicants usually use the direction from which the winds originate, the sector data must be rotated 180° for use in GRONK.

TABLE III-A-22

FILE TONIC

THE FILE TONIC IS A TABLE OF SIGMA-Z VERSUS RANGE USED BY GRONK. IT IS STORED IN INTERNAL FORMAT. HENCE IT CANNOT BE LISTED DIRECTLY. THE TABLE BELOW GIVES THE CONTENTS OF TONIC.

RANGE, METERS	PASQUILL A	PASQUILL B	PASQUILL C	PASQUILL D	PASQUILL E	PASQUILL F	PASQUILL G, G+
0	15.5	10.2	7.6	4.9	3.0	1.5	.9
100	15.5	10.2	7.6	4.9	3.0	1.5	.9
120	18.0	12.0	9.0	5.5	3.0	1.7	1.0
150	25.0	15.0	11.4	6.8	4.4	2.3	1.3
200	31.0	20.0	14.5	8.7	5.7	3.0	1.8
250	43.0	25.5	18.0	10.5	7.1	3.8	2.3
300	55.0	31.0	21.0	12.1	8.3	4.7	2.8
400	90.0	43.0	28.0	15.8	11.0	6.2	3.7
500	135.0	55.0	34.0	19.0	13.0	7.7	4.6
600	200.0	70.0	40.8	22.0	15.0	9.0	5.4
700	270.0	85.0	47.0	24.7	17.0	10.2	6.1
800	380.0	100.0	52.5	27.5	19.0	11.5	6.9
900	530.0	120.0	59.0	30.0	20.4	12.7	7.6
1000	740.9	140.0	64.0	32.0	22.0	13.5	8.1
1500	1000.0	243.0	93.0	44.0	30.0	18.3	11.0
2000	1000.0	400.0	116.0	53.5	37.0	21.7	13.0
3000	1000.0	900.0	165.0	70.0	46.5	27.6	16.6
4000	1000.0	1000.0	210.0	84.0	55.0	32.0	19.2
5000	1000.0	1000.0	249.0	96.0	61.0	35.5	21.3
6000	1000.0	1000.0	300.0	105.0	67.0	38.6	23.2
7000	1000.0	1000.0	340.0	118.0	71.0	41.2	24.7
8000	1000.0	1000.0	380.0	128.0	77.0	44.0	26.4
9000	1000.0	1000.0	405.0	135.0	80.0	46.0	27.6
10000	1000.0	1000.0	440.0	145.0	84.0	48.0	28.8
15000	1000.0	1000.0	618.0	175.0	98.0	56.0	33.6
20000	1000.0	1000.0	760.0	204.0	110.0	60.8	36.5
30000	1000.0	1000.0	1000.0	248.0	125.0	70.0	42.0
40000	1000.0	1000.0	1000.0	290.0	135.0	75.0	45.0
50000	1000.0	1000.0	1000.0	320.0	145.0	80.0	48.0
60000	1000.0	1000.0	1000.0	348.0	155.0	83.0	49.8
70000	1000.0	1000.0	1000.0	380.0	160.0	87.0	52.2
80000	1000.0	1000.0	1000.0	400.0	165.0	90.0	54.0
90000	1000.0	1000.0	1000.0	420.0	175.0	92.0	55.2
100000	1000.0	1000.0	1000.0	440.0	175.0	93.0	55.8
1E38	1000.0	1000.0	1000.0	440.0	175.0	93.0	55.8

TABLE III-A-23

TELETYPE PRINTOUT FOR SAMPLE GRONK RUN

```
RUN GRONK

GRONK   13:11   01/14/74

REACTOR NAME?MARC FOUR

OPTION WORD?LTMW
ENTER COMMENTS FOR THIS CASE?SAMPLE GRONK RUN
RELEASE HEIGHT+UNITS=?30M
ENTER GRAZING PERIOD, VEGETABLE CONSUMPTION PERIOD (MO/YR)?10 5
ENTER 2-YEAR-OLD VEG CONSUMPTION, ADULT VEG CONSUMPTION (KG/YR)?18 72
ENTER THYROID RANGES IN MILES.  END THE SET WITH A BLANK LINE
7.5 1.5
?

POPULATION TOTAL BODY DOSE= .72 MANREM/YEAR

OPTION WORD?E
NOW AT END
SRU'S:16.3
READY
```

Wake Factor

- Option W: in Equation 9, σ_z^2 is everywhere replaced by σ_z^2 + (building height)$^2/2\pi$ but is not allowed to increase beyond the maximum value of $3\sigma_z^2$. The building height is that specified in paragraph 8e of Table III-A-21.

- Option W not selected: no building-wake correction is applied.

Wind Speed

- Option M: let h_a be the larger of the effluent release height or 10 meters. Let h_s be the wind sensor height specified in paragraph 8d of Table III-A-21. Then the average wind speeds $\bar{u}_j$ are corrected by the factor $(h_a/h_s)^{0.25}$ for Hanford neutral and unstable, and for Pasquill A, B, C and D stability conditions; and by the factor $(h_a/h_s)^{0.5}$ for Hanford moderately stable and very stable, and for Pasquill E, F, G and G+ stability conditions.

- Option M not selected: no meteorological height correction factor is applied.

Thyroid

- Option T: a thyroid dose calculation will follow the skin and whole body dose calculations. GRONK will ask the user to enter grazing period, vegetable consumption periods and desired ranges for the thyroid calculation. Special feature: if the user presses the "escape" key when asked to enter thyroid ranges, the ranges previously selected for external doses are automatically used.

- Option T not selected: no thyroid calculation is made.

Adding Tables. Sometimes to sum the doses for a group of successive cases is desirable; for example, when both stack and vent releases occur. To invoke this feature, the option letter A is used for all cases except the last case in the group. GRONK will compute and print both summed and unsummed tables.

Printing Tables at Teletype. The user may select as many options as desired from the list in Table III-A-20. If printing option "8" is not chosen, the integrated man-rem whole body dose to population, if calculated, will be printed at the teletype. The selected tables will be printed at the teletype in the same format as they appear on the high-speed printer output. Some of the tables may be folded unless the user's conversational terminal has a width of at least 125 columns.

More than one set of release rates may be stored on the file Gxxxx. If GRONK determines that more than one list of releases is present, it will ask the user to enter the name of the desired list. (This feature was not used in the sample run.)

When the case is completed, GRONK will again request an option word. If the user desires to run another case for the same facility, he may enter another option word as described above. To indicate that the run is completed, he enters one of the following option letters:

- E End the run

- F End the run, then end the session as if an OFF command had been issued

- N End the run, then rerun GRONK for a new facility.

Table III-A-24 shows the high-speed printer output resulting from the sample run.* On the last page is a summary of all cases contained in the printout.

III-A.7.5 Mixing Ratios and Reconcentration Formula

Mixing ratios and reconcentration factors are required by both ARRRG and CRITR. This section discusses the methods of choosing the proper parameters to use as input for these sections of the programs.

The mixing ratio M_p, best determined from hydrological studies, accounts for the dilution of the liquid effluent between the point of discharge and the point of exposure. If the temperature increase which would result at the point of exposure solely from mixing is known, then the mixing ratio may be estimated from

$$M_p = \frac{T_p - T_A}{T_0 - T_A}$$

where T_A = ambient temperature of the receiving sink
T_p = temperature which would exist at the point of exposure for pathway p if no evaporation or radiation effects were present
T_0 = temperature of the effluent at the outlet.

The value for T_p can be estimated from a plot of isotherms due to mixing only in the receiving waters.

* The thyroid dose factors listed in the sample runs and program listings, and the thyroid doses calculated in the sample GRONK are incorrect. The dose factors have been changed since the listings were prepared. The correct values are shown in Tables III-A-6, -7 and -8. The program now calculates thyroid doses for a 1-yr old and an adult.

TABLE III-A-24

HIGH-SPEED PRINTER OUTPUT FOR SAMPLE GRONK RUN(a)

GRONK ** GRONK ** GRONK ** GRONK ** GRONK 01/14/74 13:12 GRONK ** GRONK ** GRONK ** GRONK ** GRONK

1 9 8 0 P O P U L A T I O N T A B L E

RANGE	.5 MI	1.5 MI	2.5 MI	3.5 MI	4.5 MI	7.5 MI	15 MI	25 MI	35 MI	45 MI	TOTALS
N	0	0	29	21	67	575	37,850	131,050	18,000	13,200	200,792
NNE	0	3	67	218	80	831	7,950	14,450	15,650	6,850	46,099
NE	0	15	0	70	33	2,486	59,950	55,050	17,800	12,000	147,404
ENE	0	0	0	0	17	989	53,250	52,800	20,950	11,850	139,856
E	0	0	0	0	5	1,604	7,250	9,900	7,250	12,950	39,159
ESE	0	0	0	0	17	3,511	6,000	4,950	19,100	14,100	47,678
SE	0	0	0	0	12	953	4,900	15,150	6,100	6,700	33,815
SSE	0	0	0	0	10	430	4,500	12,500	33,750	23,850	75,040
S	0	0	0	0	0	82	3,250	12,450	83,850	88,350	187,982
SSW	0	0	0	0	37	314	5,650	5,900	6,450	11,400	29,751
SW	0	0	0	7	34	196	7,900	10,850	6,250	16,300	41,537
WSW	0	0	0	38	48	743	6,750	6,950	7,500	9,300	31,329
W	0	0	4	90	34	833	2,150	4,050	9,500	31,000	47,661
WNW	0	0	83	18	64	131	3,800	3,950	15,350	17,850	41,246
NW	0	2	7	0	22	162	2,150	7,750	16,250	72,900	99,243
NNW	0	19	82	18	15	131	37,650	13,250	16,750	15,350	83,265
TOTALS	0	39	272	480	495	14,171	250,950	361,000	300,500	363,950	1,291,857
CUM TOTL	0	39	311	791	1,286	15,457	266,407	627,407	927,907	1,291,857	1,291,857

MARC FOUR 2 UNITS 01/14/74

PASQUILL A CATEGORY
METEOROLOGY AS INPUT FROM FILE
PERCENT OF ALL OCCURRENCES

	0-3	4-7	8-12	13-18	19+	TOTALS
N	.05	.07	.03	.00	.00	.16
NNE	.03	.05	.02	.01	.00	.11
NE	.08	.12	.06	.00	.00	.25
ENE	.01	.12	.05	.00	.00	.17
E	.08	.15	.03	.00	.00	.27
ESE	.03	.13	.05	.00	.00	.21
SE	.06	.20	.03	.01	.00	.30
SSE	.06	.09	.02	.01	.00	.18
S	.08	.08	.02	.00	.00	.18
SSW	.04	.03	.01	.00	.00	.09
SW	.03	.08	.07	.00	.00	.18
WSW	.03	.08	.05	.00	.00	.16
W	.05	.14	.02	.00	.00	.21
WNW	.02	.08	.01	.00	.00	.11
NW	.03	.05	.02	.00	.00	.10
NNW	.02	.12	.00	.00	.00	.14
VARBL	.00	.00	.00	.00	.00	.00
CALM	.00					.00
TOTALS	.69	1.57	.51	.03	.00	2.80

PASQUILL A CATEGORY
METEOROLOGY IN STANDARD FORM
PERCENT OF ALL OCCURRENCE

	0-3	4-7	8-12	13-18	19+	TOTALS
N	.05	.07	.03	.00	.00	.16
NNE	.03	.05	.02	.01	.00	.11
NE	.08	.12	.06	.00	.00	.25
ENE	.01	.12	.05	.00	.00	.17
E	.08	.15	.03	.00	.00	.27
ESE	.03	.13	.05	.00	.00	.21
SE	.06	.20	.03	.01	.00	.30
SSE	.06	.09	.02	.01	.00	.18
S	.08	.08	.02	.00	.00	.18
SSW	.04	.03	.01	.00	.00	.09
SW	.03	.08	.07	.00	.00	.18
WSW	.03	.08	.05	.00	.00	.16
W	.05	.14	.02	.00	.00	.21
WNW	.02	.08	.01	.00	.00	.11
NW	.03	.05	.02	.00	.00	.10
NNW	.02	.12	.00	.00	.00	.14
TOTALS	.69	1.57	.51	.03	.00	2.80

(a) The thyroid dose factors listed in the sample runs and program listings, and the thyroid doses calculated in the sample GRONK are incorrect. The dose factors have been changed since the listings were prepared. The correct values are shown in Tables III-A-6, -7 and -8. The program now calculates thyroid doses for a 1-year old and an adult.

TABLE III-A-24 (Continued)

MARC FOUR 2 UNITS

01/14/74

PASQUILL B CATEGORY
METEOROLOGY AS INPUT FROM FILE
PERCENT OF ALL OCCURRENCES

	0-3	4-7	8-12	13-18	19+	TOTALS
N	.11	.24	.06	.00	.00	.41
NNE	.05	.09	.07	.00	.00	.22
NE	.13	.31	.33	.02	.00	.80
ENE	.04	.31	.38	.03	.00	.77
E	.09	.28	.21	.06	.00	.63
ESE	.04	.18	.10	.00	.00	.32
SE	.04	.20	.23	.05	.00	.51
SSE	.04	.13	.08	.00	.00	.25
S	.13	.27	.20	.02	.00	.61
SSW	.01	.09	.13	.01	.00	.24
SW	.05	.17	.25	.02	.00	.50
WSW	.02	.07	.15	.03	.00	.27
W	.03	.24	.20	.00	.00	.47
WNW	.05	.15	.07	.01	.00	.28
NW	.05	.22	.02	.00	.00	.29
NNW	.04	.09	.07	.00	.00	.20
VARBL	.00	.00	.00	.00	.00	.00
CALM	.00					.00
TOTALS	.91	3.05	2.55	.27	.00	6.77

PASQUILL B CATEGORY
METEOROLOGY IN STANDARD FORM
PERCENT OF ALL OCCURRENCE

	0-3	4-7	8-12	13-18	19+	TOTALS
N	.11	.24	.06	.00	.00	.41
NNE	.05	.09	.07	.00	.00	.22
NE	.13	.31	.33	.02	.00	.80
ENE	.04	.31	.38	.03	.00	.77
E	.09	.28	.21	.06	.00	.63
ESE	.04	.18	.10	.00	.00	.32
SE	.04	.20	.23	.05	.00	.51
SSE	.04	.13	.08	.00	.00	.25
S	.13	.27	.20	.02	.00	.61
SSW	.01	.09	.13	.01	.00	.24
SW	.05	.17	.25	.02	.00	.50
WSW	.02	.07	.15	.03	.00	.27
W	.03	.24	.20	.00	.00	.47
WNW	.05	.15	.07	.01	.00	.28
NW	.05	.22	.02	.00	.00	.29
NNW	.04	.09	.07	.00	.00	.20
TOTALS	.91	3.05	2.55	.27	.00	6.77

MARC FOUR 2 UNITS

01/14/74

PASQUILL C CATEGORY
METEOROLOGY AS INPUT FROM FILE
PERCENT OF ALL OCCURRENCES

	0-3	4-7	8-12	13-18	19+	TOTALS
N	.06	.24	.16	.05	.00	.51
NNE	.04	.18	.30	.09	.00	.62
NE	.05	.32	1.00	.30	.07	1.74
ENE	.04	.38	.92	.25	.06	1.66
E	.10	.42	.45	.24	.02	1.23
ESE	.03	.10	.25	.15	.02	.56
SE	.09	.18	.28	.14	.02	.71
SSE	.04	.15	.15	.01	.01	.36
S	.12	.18	.33	.10	.01	.75
SSW	.05	.24	.21	.03	.00	.53
SW	.06	.36	.80	.25	.02	1.49
WSW	.03	.27	.54	.12	.00	.96
W	.08	.40	.58	.06	.00	1.11
WNW	.03	.23	.31	.03	.00	.61
NW	.03	.16	.16	.01	.00	.36
NNW	.03	.16	.10	.00	.00	.30
VARBL	.00	.00	.00	.00	.00	.00
CALM	.00					.00
TOTALS	.88	3.99	6.55	1.65	.24	13.51

PASQUILL C CATEGORY
METEOROLOGY IN STANDARD FORM
PERCENT OF ALL OCCURRENCE

	0-3	4-7	8-12	13-18	19+	TOTALS
N	.06	.24	.16	.05	.00	.51
NNE	.04	.18	.30	.09	.00	.62
NE	.05	.32	1.00	.30	.07	1.74
ENE	.04	.38	.92	.25	.06	1.66
E	.10	.42	.45	.24	.02	1.23
ESE	.03	.10	.25	.15	.02	.56
SE	.09	.18	.28	.14	.02	.71
SSE	.04	.15	.15	.01	.01	.36
S	.12	.18	.33	.10	.01	.75
SSW	.05	.24	.21	.03	.00	.53
SW	.06	.36	.80	.25	.02	1.49
WSW	.03	.27	.54	.12	.00	.96
W	.08	.40	.58	.06	.00	1.11
WNW	.03	.23	.31	.03	.00	.61
NW	.03	.16	.16	.01	.00	.36
NNW	.03	.16	.10	.00	.00	.30
TOTALS	.88	3.99	6.55	1.65	.24	13.51

MARC FOUR 2 UNITS

01/14/74

PASQUILL D CATEGORY
METEOROLOGY AS INPUT FROM FILE
PERCENT OF ALL OCCURRENCES

	0-3	4-7	8-12	13-18	19+	TOTALS
N	.10	.24	.61	.22	.03	1.21
NNE	.10	.25	.85	.47	.02	1.70
NE	.15	.52	2.17	.76	.10	3.71
ENE	.07	.55	1.07	.42	.07	2.18
E	.08	.39	.47	.36	.09	1.40
ESE	.13	.28	.20	.33	.09	1.03
SE	.08	.29	.44	.54	.25	1.60
SSE	.06	.20	.33	.30	.14	1.03
S	.12	.40	.76	.43	.07	1.78
SSW	.11	.42	1.06	.37	.02	1.98
SW	.17	.82	2.08	.66	.09	3.82
WSW	.07	.42	1.28	.54	.03	2.35
W	.07	.50	.96	.12	.00	1.64
WNW	.05	.20	.28	.06	.00	.58
NW	.08	.35	.32	.08	.00	.83
NNW	.06	.16	.16	.07	.01	.46
VARBL	.00	.00	.00	.00	.00	.00
CALM	.00					.00
TOTALS	1.50	5.98	13.05	5.72	1.04	27.29

PASQUILL D CATEGORY
METEOROLOGY IN STANDARD FORM
PERCENT OF ALL OCCURRENCE

	0-3	4-7	8-12	13-18	19+	TOTALS
N	.10	.24	.61	.22	.03	1.21
NNE	.10	.25	.85	.47	.02	1.70
NE	.15	.52	2.17	.76	.10	3.71
ENE	.07	.55	1.07	.42	.07	2.18
E	.08	.39	.47	.36	.09	1.40
ESE	.13	.28	.20	.33	.09	1.03
SE	.08	.29	.44	.54	.25	1.60
SSE	.06	.20	.33	.30	.14	1.03
S	.12	.40	.76	.43	.07	1.78
SSW	.11	.42	1.06	.37	.02	1.98
SW	.17	.82	2.08	.66	.09	3.82
WSW	.07	.42	1.28	.54	.03	2.35
W	.07	.50	.96	.12	.00	1.64
WNW	.05	.20	.28	.06	.00	.58
NW	.08	.35	.32	.08	.00	.83
NNW	.06	.16	.16	.07	.01	.46
TOTALS	1.50	5.98	13.05	5.72	1.04	27.29

TABLE III-A-24 (Continued)

MARC FOUR 2 UNITS — 01/14/74

PASQUILL E CATEGORY
METEOROLOGY AS INPUT FROM FILE
PERCENT OF ALL OCCURRENCES

	0-3	4-7	8-12	13-18	19+	TOTALS
N	.20	.43	.55	.07	.00	1.25
NNE	.07	.32	.75	.09	.00	1.24
NE	.21	.75	1.85	.20	.00	3.00
ENE	.13	.46	.54	.03	.00	1.17
E	.15	.53	.24	.03	.00	.95
ESE	.16	.17	.20	.09	.01	.63
SE	.26	.43	.73	.32	.13	1.87
SSE	.21	.31	.61	.37	.06	1.56
S	.15	.44	.97	.38	.06	2.00
SSW	.12	.32	.67	.12	.01	1.24
SW	.18	.73	1.21	.13	.00	2.25
WSW	.05	.37	.45	.05	.00	.92
W	.16	.53	.40	.02	.00	1.12
WNW	.08	.35	.23	.01	.00	.66
NW	.12	.40	.36	.01	.00	.89
NNW	.15	.46	.24	.05	.00	.90
VARBL	.00	.00	.00	.00	.00	.00
CALM	.00					.00
TOTALS	2.41	7.00	10.00	1.97	.27	21.66

PASQUILL E CATEGORY
METEOROLOGY IN STANDARD FORM
PERCENT OF ALL OCCURRENCE

	0-3	4-7	8-12	13-18	19+	TOTALS
N	.20	.43	.55	.07	.00	1.25
NNE	.07	.32	.75	.09	.00	1.24
NE	.21	.75	1.85	.20	.00	3.00
ENE	.13	.46	.54	.03	.00	1.17
E	.15	.53	.24	.03	.00	.95
ESE	.16	.17	.20	.09	.01	.63
SE	.26	.43	.73	.32	.13	1.87
SSE	.21	.31	.61	.37	.06	1.56
S	.15	.44	.97	.38	.06	2.00
SSW	.12	.32	.67	.12	.01	1.24
SW	.18	.73	1.21	.13	.00	2.25
WSW	.05	.37	.45	.05	.00	.92
W	.16	.53	.40	.02	.00	1.12
WNW	.08	.35	.23	.01	.00	.66
NW	.12	.40	.36	.01	.00	.89
NNW	.15	.46	.24	.05	.00	.90
TOTALS	2.41	7.00	10.00	1.97	.27	21.66

MARC FOUR 2 UNITS — 01/14/74

PASQUILL F CATEGORY
METEOROLOGY AS INPUT FROM FILE
PERCENT OF ALL OCCURRENCES

	0-3	4-7	8-12	13-18	19+	TOTALS
N	.21	.72	1.29	.03	.00	2.26
NNE	.15	.66	1.50	.03	.00	2.35
NE	.21	1.08	2.80	.05	.00	4.14
ENE	.24	.87	.96	.00	.00	2.07
E	.28	.74	.50	.05	.00	1.56
ESE	.19	.44	.32	.02	.00	.98
SE	.16	.57	.73	.07	.00	1.52
SSE	.14	.55	.55	.10	.00	1.35
S	.22	.69	.88	.05	.00	1.84
SSW	.22	.54	.80	.02	.00	1.58
SW	.15	.69	1.04	.03	.00	1.91
WSW	.10	.45	.53	.01	.00	1.10
W	.07	.37	.77	.00	.00	1.21
WNW	.09	.43	.60	.01	.00	1.13
NW	.20	.68	1.03	.01	.00	1.92
NNW	.15	.43	.46	.02	.00	1.06
VARBL	.00	.00	.00	.00	.00	.00
CALM	.00					.00
TOTALS	2.79	9.90	14.76	.52	.00	27.97

PASQUILL F CATEGORY
METEOROLOGY IN STANDARD FORM
PERCENT OF ALL OCCURRENCE

	0-3	4-7	8-12	13-18	19+	TOTALS
N	.21	.72	1.29	.03	.00	2.26
NNE	.15	.66	1.50	.03	.00	2.35
NE	.21	1.08	2.80	.05	.00	4.14
ENE	.24	.87	.96	.00	.00	2.07
E	.28	.74	.50	.05	.00	1.56
ESE	.19	.44	.32	.02	.00	.98
SE	.16	.57	.73	.07	.00	1.52
SSE	.14	.55	.55	.10	.00	1.35
S	.22	.69	.88	.05	.00	1.84
SSW	.22	.54	.80	.02	.00	1.58
SW	.15	.69	1.04	.03	.00	1.91
WSW	.10	.45	.53	.01	.00	1.10
W	.07	.37	.77	.00	.00	1.21
WNW	.09	.43	.60	.01	.00	1.13
NW	.20	.68	1.03	.01	.00	1.92
NNW	.15	.43	.46	.02	.00	1.06
TOTALS	2.79	9.90	14.76	.52	.00	27.97

TABLE III-A-24 (Continued)

CASE 1: HANC FOUR 2 UNITS 30 METER RELEASE SAMPLE GRONK RUN 01/14/74

ISOTOPE	RELEASE CI/YEAR	LAMBDA 1/SEC	EXTERNAL DOSE FACTORS MREM/HR PER PCI/CUBIC METER TOTAL BODY	SKIN	THYROID DOSE FACTORS -- MREM/YEAR PER PCI/CUBIC METER(a) ---INHALATION--- 2 YEAR	ADULT	-----M I L K------ 2 YEAR	ADULT	LEAFY VEGETABLES 2 YEAR	ADULT
29 KR-83M	11.896	1.04E-04	0	7.6E-10						
30 KR-85M	64.16	4.39E-05	1.3E-07	3.2E-07						
31 KR-85	3186.8	2.04E-09	2.2E-09	1.6E-07						
32 KR-87	34.616	1.52E-04	1.3E-06	2.7E-06						
33 KR-88	111.12	6.86E-05	1.5E-06	2.0E-06						
36 RB-89	9.546	7.50E-04	2.1E-06	2.8E-06						
82 I-131	0.178	9.97E-07	3.1E-07	4.9E-07	12.5	10.6	3620.	448.	1190.	589.
84 I-133	0.130	9.17E-06	4.4E-07	8.8E-07	5.51	2.70	262.	18.7	84.1	24.1
87 XE-131M	80.04	6.81E-07	2.8E-09	4.8E-08						
88 XE-133M	123.46	3.56E-06	2.7E-08	6.0E-08						
89 XE-133	10036	1.52E-06	2.5E-08	6.9E-08						
90 XE-135M	7.352	7.42E-04	3.5E-07	5.0E-07						
91 XE-135	186.88	2.09E-05	2.1E-07	4.9E-07						
92 XE-137	5.392	2.97E-03	1.2E-07	1.8E-06						
93 XE-138	25.544	6.81E-04	1.2E-06	1.7E-06						

PASQUILL MODEL
30 METER RELEASE
BUILT-IN TOTAL BODY/SKIN RANGES
BUILDING WAKE FACTOR APPLIED. BUILDING HEIGHT= 56.3 METERS
WIND SPEEDS CORRECTED FROM 36.576 METERS TO 30 METERS
PERFORM THYROID CALCULATION
GRAZING PERIOD= 10 MONTHS/YEAR
VEGETABLE CONSUMPTION PERIOD= 5 MONTHS/YEAR
2-YEAR-OLD VEGETABLE CONSUMPTION= 18 KILOGRAMS/YEAR
ADULT VEGETABLE CONSUMPTION= 72 KILOGRAMS/YEAR

CASE 1: HANC FOUR 2 UNITS 30 METER RELEASE SAMPLE GRONK RUN 01/14/74

CONTRIBUTION TO DOSE AT RELEASE POINT

ISOTOPE	TOTAL BODY	SKIN	INHALATION 2 YR	ADULT	---MILK---- 2 YR	ADULT	VEGETABLES 2 YR	ADULT
31 KR-85		30 %						
32 KR-87	8 %	5 %						
33 KR-88	10 %	13 %						
82 I-131			89 %	80 %	93 %	90 %	93 %	90 %
84 I-133			11 %	20 %	7 %		7 %	
89 XE-133	45 %	41 %						
91 XE-135	7 %	5 %						
93 XE-138	5 %							

CASE 1: HANC FOUR 2 UNITS 30 METER RELEASE SAMPLE GRONK RUN 01/14/74

TABLE OF CHI/Q PASQUILL MODEL

RANGE	.5 MI	1.5 MI	2.5 MI	3.5 MI	4.5 MI	7.5 MI	15 MI	25 MI	35 MI	45 MI	TOTALS
N	9.34E-07	2.48E-07	1.17E-07	7.50E-08	5.25E-08	2.60E-08	1.03E-08	5.81E-09	3.66E-09	2.66E-09	1.48E-06
NNE	8.73E-07	2.30E-07	1.10E-07	6.99E-08	4.88E-08	2.41E-08	9.47E-09	5.24E-09	3.41E-09	2.47E-09	1.38E-06
NE	1.79E-06	4.46E-07	2.12E-07	1.35E-07	9.39E-08	4.61E-08	1.81E-08	1.01E-08	6.36E-09	4.73E-09	2.77E-06
ENE	1.09E-06	2.68E-07	1.27E-07	8.14E-08	5.66E-08	2.77E-08	1.09E-08	6.05E-09	3.94E-09	2.85E-09	1.67E-06
E	9.29E-07	2.30E-07	1.09E-07	7.03E-08	4.91E-08	2.41E-08	9.47E-09	5.22E-09	3.41E-09	2.46E-09	1.43E-06
ESE	6.13E-07	1.53E-07	7.29E-08	4.63E-08	3.23E-08	1.59E-08	6.25E-09	3.49E-09	2.27E-09	1.64E-09	9.47E-07
SE	9.40E-07	2.27E-07	1.08E-07	6.83E-08	4.76E-08	2.34E-08	9.18E-09	5.05E-09	3.28E-09	2.38E-09	1.43E-06
SSE	7.38E-07	1.80E-07	8.67E-08	5.61E-08	3.92E-08	1.94E-08	7.63E-09	4.16E-09	2.70E-09	1.96E-09	1.14E-06
S	1.06E-06	2.59E-07	1.23E-07	7.83E-08	5.46E-08	2.68E-08	1.05E-08	5.85E-09	3.80E-09	2.76E-09	1.63E-06
SSW	8.76E-07	2.17E-07	1.03E-07	6.59E-08	4.58E-08	2.24E-08	8.77E-09	4.95E-09	3.20E-09	2.31E-09	1.35E-06
SW	1.41E-06	3.20E-07	1.50E-07	9.46E-08	6.53E-08	3.17E-08	1.22E-08	7.06E-09	4.55E-09	3.27E-09	2.10E-06
WSW	7.54E-07	1.73E-07	8.11E-08	5.10E-08	3.50E-08	1.72E-08	6.84E-09	3.88E-09	2.49E-09	1.79E-09	1.13E-06
W	8.28E-07	1.96E-07	8.67E-08	5.57E-08	3.85E-08	1.87E-08	7.21E-09	4.09E-09	2.65E-09	1.92E-09	1.23E-06
WNW	5.11E-07	1.29E-07	6.14E-08	3.94E-08	2.75E-08	1.35E-08	5.32E-09	2.91E-09	1.90E-09	1.38E-09	7.93E-07
NW	7.44E-07	2.01E-07	9.72E-08	6.16E-08	4.32E-08	2.14E-08	8.49E-09	4.83E-09	3.01E-09	2.19E-09	1.19E-06
NNW	5.65E-07	1.40E-07	7.01E-08	4.45E-08	3.12E-08	1.54E-08	6.09E-09	3.29E-09	2.14E-09	1.59E-09	8.88E-07
TOTALS	1.47E-05	3.62E-06	1.72E-06	1.09E-06	7.62E-07	3.74E-07	1.46E-07	8.18E-08	5.30E-08	3.83E-08	2.26E-05
CUM TOTL	1.47E-05	1.83E-05	2.00E-05	2.11E-05	2.19E-05	2.22E-05	2.24E-05	2.25E-05	2.25E-05	2.26E-05	2.26E-05

(a) The thyroid dose factors listed in the sample runs and program listings, and the thyroid doses calculated in the sample GRONK are incorrect. The dose factors have been changed since the listings were prepared. The correct values are shown in Tables III-A-6, -7 and -8. The program now calculates thyroid doses for a 1-year old and an adult.

TABLE III-A-24 (Continued)

CASE 1: MARC FOUR 2 UNITS 30 METER RELEASE SAMPLE GRONK RUN 01/14/74

SKIN DOSE TO INDIVIDUAL, MREM/YEAR PASQUILL MODEL

RANGE	.5 MI	1.5 MI	2.5 MI	3.5 MI	4.5 MI	7.5 MI	15 MI	25 MI	35 MI	45 MI	TOTALS
N	4.33E-01	1.11E-01	5.20E-02	3.25E-02	2.24E-02	1.07E-02	3.98E-03	2.07E-03	1.30E-03	9.21E-04	6.70E-01
NNE	4.05E-01	1.04E-01	4.90E-02	3.06E-02	2.11E-02	1.00E-02	3.73E-03	1.97E-03	1.24E-03	8.70E-04	6.27E-01
NE	8.33E-01	2.02E-01	9.46E-02	5.91E-02	4.06E-02	1.93E-02	7.17E-03	3.80E-03	2.38E-03	1.68E-03	1.26E+00
ENE	5.02E-01	1.21E-01	5.61E-02	3.54E-02	2.42E-02	1.14E-02	4.21E-03	2.24E-03	1.41E-03	9.94E-04	7.58E-01
E	4.29E-01	1.03E-01	4.79E-02	3.03E-02	2.08E-02	9.82E-03	3.62E-03	1.90E-03	1.20E-03	8.49E-04	6.49E-01
ESE	2.83E-01	6.83E-02	3.18E-02	1.98E-02	1.36E-02	6.42E-03	2.37E-03	1.26E-03	7.92E-04	5.59E-04	4.28E-01
SE	4.35E-01	1.02E-01	4.74E-02	2.96E-02	2.03E-02	9.63E-03	3.56E-03	1.87E-03	1.17E-03	8.29E-04	6.51E-01
SSE	3.41E-01	8.35E-02	3.90E-02	2.43E-02	1.67E-02	7.96E-03	2.96E-03	1.53E-03	9.63E-04	6.81E-04	5.19E-01
S	4.91E-01	1.17E-01	5.43E-02	3.39E-02	2.33E-02	1.11E-02	4.09E-03	2.17E-03	1.36E-03	9.60E-04	7.39E-01
SSW	4.06E-01	9.87E-02	4.60E-02	2.85E-02	1.96E-02	9.24E-03	3.40E-03	1.83E-03	1.14E-03	8.02E-04	6.15E-01
SW	6.55E-01	1.45E-01	6.64E-02	4.13E-02	2.81E-02	1.32E-02	4.80E-03	2.65E-03	1.65E-03	1.15E-03	9.59E-01
WSW	3.50E-01	7.84E-02	3.60E-02	2.26E-02	1.53E-02	7.18E-03	2.61E-03	1.45E-03	9.03E-04	6.32E-04	5.15E-01
W	3.84E-01	8.40E-02	3.84E-02	2.42E-02	1.65E-02	7.74E-03	2.82E-03	1.52E-03	9.54E-04	6.72E-04	5.60E-01
WNW	2.37E-01	5.81E-02	2.71E-02	1.71E-02	1.18E-02	5.59E-03	2.07E-03	1.08E-03	6.78E-04	4.81E-04	3.61E-01
NW	3.44E-01	9.06E-02	4.28E-02	2.67E-02	1.84E-02	8.80E-03	3.28E-03	1.70E-03	1.07E-03	7.57E-04	5.38E-01
NNW	2.61E-01	6.55E-02	3.07E-02	1.91E-02	1.32E-02	6.27E-03	2.33E-03	1.20E-03	7.53E-04	5.34E-04	4.00E-01
TOTALS	6.79E+00	1.63E+00	7.59E-01	4.75E-01	3.26E-01	1.54E-01	5.70E-02	3.02E-02	1.90E-02	1.34E-02	1.03E+01
CUM TOTL	6.79E+00	8.42E+00	9.18E+00	9.65E+00	9.98E+00	1.01E+01	1.02E+01	1.02E+01	1.02E+01	1.03E+01	1.03E+01

CASE 1: MARC FOUR 2 UNITS 30 METER RELEASE SAMPLE GRONK RUN 01/14/74

TOTAL BODY DOSE TO INDIVIDUAL, MREM/YEAR PASQUILL MODEL

RANGE	.5 MI	1.5 MI	2.5 MI	3.5 MI	4.5 MI	7.5 MI	15 MI	25 MI	35 MI	45 MI	TOTALS
N	1.40E-01	3.47E-02	1.60E-02	9.83E-03	6.08E-03	3.06E-03	1.06E-03	5.19E-04	3.13E-04	2.14E-04	2.12E-01
NNE	1.31E-01	3.29E-02	1.52E-02	9.35E-03	6.35E-03	2.92E-03	1.02E-03	5.05E-04	3.03E-04	2.06E-04	2.00E-01
NE	2.69E-01	6.42E-02	2.95E-02	1.81E-02	1.23E-02	5.65E-03	1.96E-03	9.83E-04	5.89E-04	4.01E-04	4.03E-01
ENE	1.62E-01	3.80E-02	1.73E-02	1.08E-02	7.25E-03	3.29E-03	1.13E-03	5.66E-04	3.40E-04	2.32E-04	2.41E-01
E	1.38E-01	3.23E-02	1.47E-02	9.12E-03	6.14E-03	2.78E-03	9.49E-04	4.68E-04	2.83E-04	1.94E-04	2.05E-01
ESE	9.09E-02	2.13E-02	9.70E-03	5.93E-03	3.99E-03	1.80E-03	6.16E-04	3.08E-04	1.85E-04	1.27E-04	1.35E-01
SE	1.40E-01	3.21E-02	1.46E-02	8.96E-03	6.06E-03	2.76E-03	9.51E-04	4.70E-04	2.82E-04	1.93E-04	2.08E-01
SSE	1.10E-01	2.62E-02	1.20E-02	7.34E-03	4.98E-03	2.26E-03	7.88E-04	3.85E-04	2.31E-04	1.58E-04	1.64E-01
S	1.58E-01	3.68E-02	1.68E-02	1.03E-02	6.96E-03	3.17E-03	1.10E-03	5.45E-04	3.27E-04	2.24E-04	2.35E-01
SSW	1.31E-01	3.10E-02	1.42E-02	8.65E-03	5.83E-03	2.65E-03	9.07E-04	4.59E-04	2.75E-04	1.87E-04	1.95E-01
SW	2.12E-01	4.50E-02	2.06E-02	1.26E-02	8.47E-03	3.83E-03	1.30E-03	6.77E-04	4.03E-04	2.72E-04	3.08E-01
WSW	1.13E-01	2.48E-02	1.12E-02	6.90E-03	4.62E-03	2.09E-03	7.09E-04	3.71E-04	2.21E-04	1.49E-04	1.64E-01
W	1.24E-01	2.65E-02	1.19E-02	7.39E-03	4.96E-03	2.24E-03	7.62E-04	3.87E-04	2.31E-04	1.58E-04	1.78E-01
WNW	7.63E-02	1.83E-02	8.39E-03	5.21E-03	3.53E-03	1.61E-03	5.56E-04	2.71E-04	1.63E-04	1.12E-04	1.14E-01
NW	1.11E-01	2.85E-02	1.32E-02	8.08E-03	5.49E-03	2.52E-03	8.75E-04	4.26E-04	2.56E-04	1.75E-04	1.70E-01
NNW	8.39E-02	2.05E-02	9.41E-03	5.75E-03	3.90E-03	1.78E-03	6.12E-04	2.95E-04	1.77E-04	1.22E-04	1.26E-01
TOTALS	2.19E+00	5.14E-01	2.35E-01	1.44E-01	9.75E-02	4.44E-02	1.53E-02	7.64E-03	4.58E-03	3.12E-03	3.26E+00
CUM TOTL	2.19E+00	2.70E+00	2.94E+00	3.08E+00	3.18E+00	3.23E+00	3.24E+00	3.25E+00	3.25E+00	3.26E+00	3.26E+00

CASE 1: MARC FOUR 2 UNITS 30 METER RELEASE SAMPLE GRONK RUN 01/14/74

TOTAL BODY DOSE TO POPULATION, MAN-REM/YEAR PASQUILL MODEL

RANGE	.5 MI	1.5 MI	2.5 MI	3.5 MI	4.5 MI	7.5 MI	15 MI	25 MI	35 MI	45 MI	TOTALS
N	.00E+00	.00E+00	4.65E-04	2.06E-04	4.47E-04	1.76E-03	4.02E-02	6.80E-02	5.63E-03	2.82E-03	1.20E-01
NNE	.00E+00	9.87E-05	1.02E-03	2.04E-03	5.08E-04	2.43E-03	8.09E-03	7.30E-03	4.74E-03	1.41E-03	2.76E-02
NE	.00E+00	9.62E-04	.00E+00	1.27E-03	4.06E-04	1.40E-02	1.18E-01	5.41E-02	1.05E-02	4.81E-03	2.04E-01
ENE	.00E+00	.00E+00	.00E+00	.00E+00	1.23E-04	3.26E-03	6.02E-02	2.99E-02	7.12E-03	2.75E-03	1.03E-01
E	.00E+00	.00E+00	.00E+00	.00E+00	3.07E-05	5.01E-03	6.88E-03	4.64E-03	2.05E-03	2.51E-03	2.11E-02
ESE	.00E+00	.00E+00	.00E+00	.00E+00	6.79E-05	6.33E-03	3.69E-03	1.52E-03	3.54E-03	1.79E-03	1.69E-02
SE	.00E+00	.00E+00	.00E+00	.00E+00	7.27E-05	2.63E-03	4.66E-03	7.12E-03	1.72E-03	1.30E-03	1.75E-02
SSE	.00E+00	.00E+00	.00E+00	.00E+00	4.98E-05	9.79E-04	3.54E-03	4.81E-03	7.81E-03	3.78E-03	2.10E-02
S	.00E+00	.00E+00	.00E+00	.00E+00	.00E+00	2.60E-04	3.56E-03	6.79E-03	2.75E-02	1.98E-02	5.78E-02
SSW	.00E+00	.00E+00	.00E+00	.00E+00	2.16E-04	8.31E-04	5.13E-03	2.71E-03	1.77E-03	2.13E-03	1.28E-02
SW	.00E+00	.00E+00	.00E+00	8.84E-05	2.88E-04	7.51E-04	1.03E-02	7.35E-03	2.52E-03	4.44E-03	2.57E-02
WSW	.00E+00	.00E+00	.00E+00	2.62E-04	2.22E-04	1.55E-03	4.79E-03	2.58E-03	1.66E-03	1.39E-03	1.24E-02
W	.00E+00	.00E+00	4.76E-05	6.65E-04	1.69E-04	1.86E-03	1.64E-03	1.57E-03	2.20E-03	4.88E-03	1.30E-02
WNW	.00E+00	.00E+00	6.96E-04	9.37E-05	2.26E-04	2.11E-04	2.11E-03	1.07E-03	2.51E-03	1.99E-03	8.91E-03
NW	.00E+00	5.70E-05	9.23E-05	.00E+00	1.21E-04	4.08E-04	1.88E-03	3.30E-03	4.16E-03	1.28E-02	2.28E-02
NNW	.00E+00	3.90E-04	7.71E-04	1.03E-04	5.85E-05	2.33E-04	2.30E-02	3.90E-03	2.97E-03	1.87E-03	3.33E-02
TOTALS	.00E+00	1.51E-03	3.09E-03	4.73E-03	3.01E-03	4.26E-02	2.97E-01	2.07E-01	8.83E-02	7.04E-02	7.18E-01
CUM TOTL	.00E+00	1.51E-03	4.60E-03	9.33E-03	1.23E-02	5.49E-02	3.52E-01	5.59E-01	6.47E-01	7.18E-01	7.18E-01

TABLE III-A-24 (Continued)

CASE 1: MARC FOUR 2 UNITS 30 METER RELEASE SAMPLE GRONK RUN 01/14/74

CUMULATIVE RADIUS (MILES)	CUMULATIVE 1960 POPULATION	CUMULATIVE DOSE (MAN-REM/YR)	AVERAGE ANNUAL DOSE (MREM/YR)
1	0	0	
2	39	.0015	.039
3	311	.0046	.015
4	791	.0093	.012
5	1,286	.012	.0096
10	15,457	.055	.0036
20	266,407	.35	.0013
30	627,407	.56	.00089
40	927,907	.65	.0007
50	1,291,857	.72	.00056

CASE 1: MARC FOUR 2 UNITS 30 METER RELEASE SAMPLE GRONK RUN 01/14/74

T H Y R O I D D O S E (a)
.5 MILES

PASQUILL MODEL

	CHI/Q SEC/M**3	NUCLIDE CONCENTRATION, PCI/CUBIC METER							DOSE FROM PATHWAY MREM/YR: INHALATION		MILK		LEAFY VEGETABLES	
		TE-132D	I-129	I-130	I-131	I-132	I-133	I-135	2 YR	ADULT	2 YR	ADULT	2 YR	ADULT
N	9.4E-07				5.1E-03		3.8E-03		8.4E-02	6.4E-02	1.6E+01	1.9E+00	2.6E+00	1.3E+00
NNE	8.7E-07				4.7E-03		3.6E-03		7.9E-02	6.0E-02	1.5E+01	1.8E+00	2.5E+00	1.2E+00
NE	1.8E-06				9.7E-03		7.4E-03		1.6E-01	1.2E-01	3.1E+01	3.7E+00	5.0E+00	2.4E+00
ENE	1.1E-06				5.8E-03		4.4E-03		9.7E-02	7.4E-02	1.9E+01	2.2E+00	3.0E+00	1.5E+00
E	9.3E-07				5.0E-03		3.8E-03		8.4E-02	6.3E-02	1.6E+01	1.9E+00	2.6E+00	1.3E+00
ESE	6.1E-07				3.3E-03		2.5E-03		5.5E-02	4.2E-02	1.1E+01	1.3E+00	1.7E+00	8.4E-01
SE	9.4E-07				5.1E-03		3.9E-03		8.5E-02	6.4E-02	1.6E+01	1.9E+00	2.6E+00	1.3E+00
SSE	7.4E-07				4.0E-03		3.0E-03		6.6E-02	5.0E-02	1.3E+01	1.5E+00	2.1E+00	1.0E+00
S	1.1E-06				5.7E-03		4.4E-03		9.5E-02	7.2E-02	1.8E+01	2.2E+00	3.0E+00	1.4E+00
SSW	8.8E-07				4.7E-03		3.6E-03		7.9E-02	6.0E-02	1.5E+01	1.8E+00	2.5E+00	1.2E+00
SW	1.4E-06				7.6E-03		5.8E-03		1.3E-01	9.6E-02	2.4E+01	2.9E+00	4.0E+00	1.9E+00
WSW	7.5E-07				4.1E-03		3.1E-03		6.8E-02	5.1E-02	1.3E+01	1.6E+00	2.1E+00	1.0E+00
W	8.3E-07				4.5E-03		3.4E-03		7.4E-02	5.6E-02	1.4E+01	1.7E+00	2.3E+00	1.1E+00
WNW	5.1E-07				2.8E-03		2.1E-03		4.6E-02	3.5E-02	8.8E+00	1.1E+00	1.4E+00	7.0E-01
NW	7.4E-07				4.0E-03		3.1E-03		6.7E-02	5.1E-02	1.3E+01	1.5E+00	2.1E+00	1.0E+00
NNW	5.[illegible]E-07				3.0E-03		2.3E-0[illegible]		5.1E-02	3.9E-02	9.7E+00	1.2E+00	1.6E+00	7.7E-01

CASE 1: MARC FOUR 2 UNITS 30 METER RELEASE SAMPLE GRONK RUN 01/14/74

T H Y R O I D D O S E (a)
1.5 MILES

PASQUILL MODEL

	CHI/Q SEC/M**3	NUCLIDE CONCENTRATION, PCI/CUBIC METER							DOSE FROM PATHWAY MREM/YR: INHALATION		MILK		LEAFY VEGETABLES	
		TE-132D	I-129	I-130	I-131	I-132	I-133	I-135	2 YR	ADULT	2 YR	ADULT	2 YR	ADULT
N	2.5E-07				1.3E-03		1.0E-03		2.2E-02	1.7E-02	4.2E+00	5.1E-01	6.9E-01	3.3E-01
NNE	2.3E-07				1.2E-03		9.4E-04		2.1E-02	1.6E-02	3.9E+00	4.8E-01	6.5E-01	3.1E-01
NE	4.5E-07				2.4E-03		1.8E-03		4.0E-02	3.0E-02	7.6E+00	9.3E-01	1.3E+00	6.1E-01
ENE	2.7E-07				1.4E-03		1.1E-03		2.4E-02	1.8E-02	4.6E+00	5.5E-01	7.5E-01	3.6E-01
E	2.3E-07				1.2E-03		9.3E-04		2.1E-02	1.6E-02	3.9E+00	4.8E-01	6.5E-01	3.1E-01
ESE	1.5E-07				8.2E-04		6.2E-04		1.4E-02	1.0E-02	2.6E+00	3.2E-01	4.3E-01	2.1E-01
SE	2.3E-07				1.2E-03		9.2E-04		2.0E-02	1.5E-02	3.9E+00	4.7E-01	6.4E-01	3.1E-01
SSE	1.9E-07				1.0E-03		7.5E-04		1.7E-02	1.3E-02	3.2E+00	3.8E-01	5.2E-01	2.5E-01
S	2.6E-07				1.4E-03		1.1E-03		2.3E-02	1.8E-02	4.4E+00	5.4E-01	7.3E-01	3.5E-01
SSW	2.2E-07				1.2E-03		8.9E-04		2.0E-02	1.5E-02	3.8E+00	4.5E-01	6.2E-01	3.0E-01
SW	3.2E-07				1.7E-03		1.3E-03		2.9E-02	2.2E-02	5.5E+00	6.6E-01	9.0E-01	4.4E-01
WSW	1.7E-07				9.3E-04		7.1E-04		1.6E-02	1.2E-02	3.0E+00	3.6E-01	4.9E-01	2.4E-01
W	1.9E-07				1.0E-03		7.6E-04		1.7E-02	1.3E-02	3.2E+00	3.9E-01	5.2E-01	2.5E-01
WNW	1.3E-07				6.9E-04		5.2E-04		1.2E-02	8.8E-03	2.2E+00	2.7E-01	3.6E-01	1.8E-01
NW	2.0E-07				1.1E-03		8.2E-04		1.8E-02	1.4E-02	3.4E+00	4.2E-01	5.7E-01	2.7E-01
NNW	1.5E-07				7.9E-04		5.9E-04		1.3E-02	9.9E-03	2.5E+00	3.0E-01	4.1E-01	2.0E-01

(a) The thyroid dose factors listed in the sample runs and program listings, and the thyroid doses calculated in the sample GRONK are incorrect. The dose factors have been changed since the listings were prepared. The correct values are shown in Tables III-A-6, -7 and -8. The program now calculates thyroid doses for a 1-year old and an adult.

TABLE III-A-24 (Continued)

```
SUMMARY OF RUN        MARC FOUR 2 CENTS

CASE 1:  SAMPLE GRUNK RUN
         PASQUILL MODEL   30 METER RELEASE   WAKE FACTOR   WINDSPEED   THY

GRONK ** GRONK ** GRONK ** GRONK ** GRONK        01/14/74     1?:??        GRONK ** GRONK ** GRONK ** GRONK ** GRONK

MAIL TO:  NM ROBINSON, BATTELLE-NORTHWEST, 3717 BLDG, 300 AREA, RICHLAND, WASHINGTON  99352
```

The reconcentration factor, N_i, accounts for the extent to which effluent is recycled through the reactors. ARRRG and CRITR allow the user a choice of the following reconcentration models:

(1) If the cooling water is drawn from a cooling pond, small lake or reservoir which is connected to a larger body of water or is fed by a stream, then:

$$N_i = \left[1 - \frac{(F - L)\, e^{-\lambda_i t_c}}{F + V\,\lambda_T}\right]^{-1} \tag{17}$$

(2) If the cooling water intake is downriver from the outfall or on a lake or ocean site and arranged such that recirculation occurs, then

$$N_i = \frac{1 - \left[g\, e^{-\lambda_i t_c}\right]^{n+1}}{1 - g\, e^{-\lambda_i t_c}} \tag{18}$$

(3) If there is no reconcentration, for example, if the cooling water is drawn from a river in which the outfall is below the intake, then

$$N_i = 1.0 \tag{19}$$

where g = recycle fraction (the mixing ratio at the point of intake) (unitless)

F = coolant flow (ft^3/sec)

L = makeup flow (water drawn into the intake to replace losses) (ft^3/sec)

V = pond volume (ft^3)

λ_T = pond turnover rate (sec^{-1})

t_c = cycle time (hr)

λ_i = decay constant (hr^{-1})

n = number of cycles during facility lifetime = $\frac{\text{plant life (hr)}}{t_c}$

The above three models were chosen for the programs because they apply to the most common reconcentration situations. Unusual cases could require that special reconcentration formulas be added to the program.

Equation 18 is the closed form of the series

$$N_i = 1 + G_i + G_i^2 + G_i^3 + \ldots\ldots + G_i^n \tag{19a}$$

where $G_i = g \exp(-\lambda_i t_c)$ for nuclide i.

Formula 1, the most complex of the reconcentration models, is used for sites on a cooling pond, lake or reservoir where the water is exchanged by stream flow or connection with a larger body of water such as the ocean. It can also be used for a system of cooling canals where a fresh dilution stream (makeup) is injected into the inlet pipe along with the recycled water from the cooling pond. From elementary considerations of mass balance, assuming steady state conditions and instantaneous mixing in the cooling pond, Formula 1 is of the form of Formula 2 with $n \to \infty$ and with the recycle fraction a function of hydrological parameters and the radionuclide decay constant (Figure III-A-1),

$$N_i = \left[1 - \frac{(F - L)\, e^{-\lambda_i t_c}}{(F - L) + V(\lambda_T + \frac{L}{V})}\right]^{-1} \tag{17}$$

The volume, V, for Formula 1 may be taken to be a series of canals, a pond, small bay, small lake, etc. However, the model loses credibility if V is very large since instantaneous mixing in V was assumed; therefore, Formula 2 should be used for large V.

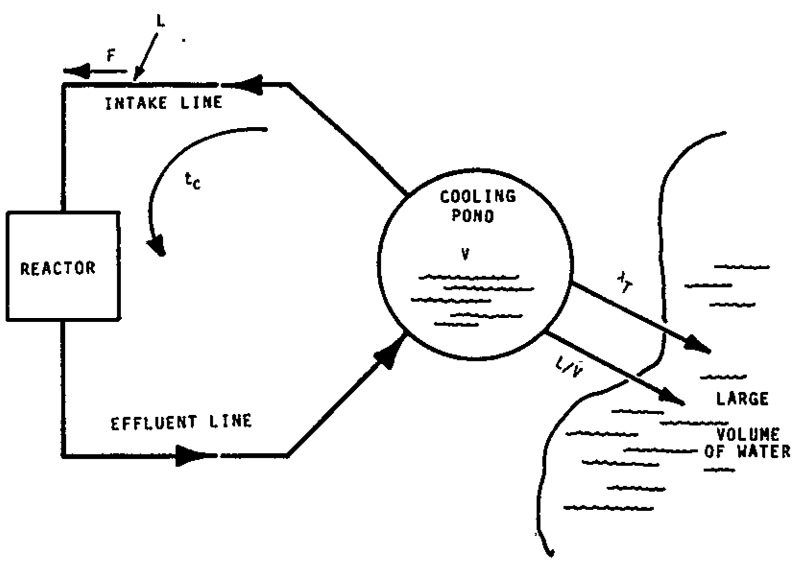

FIGURE III-A-1 RECONCENTRATION IN REACTOR EFFLUENT DUE TO RECYCLING THROUGH A COOLING POND

During an ARRRG or CRITR run, the program will ask "which reconcentration formula?" The user should then enter one of the numbers 1, 2 or 3. The programs will next ask for only those parameters which are needed for the selected reconcentration formula.

III-A.7.6 Treatment of Parent-Daughter Nuclide Pairs

Parent-daughter nuclide pairs require special consideration since decay of parent into daughter represents an additional source of the daughter nuclide in the environment and in the body. Effects of parent decay subsequent to intake into the body are already accounted for in the calculation of decay energy and internal dose factors by ICRP methods.

Accumulation of a daughter nuclide in primary aquatic organisms may be controlled by the bioaccumulation factor of either the parent or daughter, or both. To ensure that calculated doses are always conservative, a pseudo-nuclide is devised which has the half-life and bioaccumulation factors of the parent but the decay energy and dose factors of the daughter. Pseudo-nuclides are placed in the nuclide master list with a name formed by appending the letter D to the parent name. The release rate assigned to the pseudo-nuclide is the release of the parent multiplied by the fraction of the parent decay which passes through the daughter nuclide.

The doses calculated from the combination of the pseudo-nuclide plus daughter nuclide will always be at least as large as the true dose from the daughter. Furthermore, accumulation of the daughter on sediments is conservatively calculated, since the longer half-life of the parent is used for the pseudo-nuclide.

A simplification of the above method is possible when the daughter has a radiological half-life which is short compared to that of its parent and compared to the elapsed time between release of the nuclide and exposure. Since the environmental behavior of the daughter will always follow that of the parent, the decay energy of the daughter is included with that of the parent for the calculation of external dose factors. The symbol "+D" is appended to the parent name to indicate that the external dose factors are modified. Thus, whenever a parent nuclide release is specified, the result of the dose calculations will be as though an additional equilibrium amount of the daughter nuclide is specified. The daughter nuclide itself will appear separately in the master list if it can be released independently of the parent.

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APPENDIX III-A, Part 2

Program FOOD

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III-A, Part 2 Program FOOD

III-A.1 Introduction

Program FOOD is designed to calculate radiation doses to man from ingestion of foods, such as produce, milk, eggs and meat produced on farms irrigated with water containing radionuclides. Concentrations of the radionuclides in the water and ingestion dose factors (mrem/yr per pCi/yr intake) are obtained by FOOD directly from the program ARRRG previously discussed in Appendix III-A, Part 1 and in Reference 1.

FOOD is based upon the use of sprinkler irrigation since this method of application should result in higher radionuclide concentrations in plants (and animals consuming them) than surface irrigation because of foliar deposition. Surface irrigation can be simulated if necessary by setting the factor for foliar retention to zero by editing the program. In addition, the program output lists the fractions of the individual radionuclide concentrations in the plants which result from foliar deposition and from soil uptake.

The program accounts for the consumption by the animals of both contaminated feed and drinking water. Since the program output lists the radionuclide concentrations in the final product, the internal radiation dose to beef, cattle, swine and chickens could be estimated in a manner analogous to calculation of internal dose to man. The assumption would have to be made that the concentration of the radionuclides in the meat represented the average equilibrium concentration in the whole animal.

III-A.2 Irrigated Vegetation

The concentration of radioactive material in vegetation results from deposition onto the plant foliage and from uptake from the soil of prior depositions on the ground. The model used for estimating the transfer of radionuclides from irrigation water to plants through both leaves and soil to food products was derived[1] for a study of the potential doses to people from a nuclear power complex in the year 2000. The equation for the model is presented below in slightly modified form. The first term in brackets relates to the concentration derived from direct foliar deposition during the growing season; the second term, to uptake from soil, and reflects the deposition throughout the total life of the nuclear facility. Thus for a uniform release rate

$$C_{iv} = d_i \left[\frac{r\, T_v \left(1 - e^{-\lambda_{Ei} t_e}\right)}{Y_v\, \lambda_{Ei}} + \frac{B_{iv}\left(1 - e^{-\lambda_i t_b}\right)}{P\, \lambda_i} \right] e^{-\lambda_i t_h} \qquad (1)$$

where

- C_{iv} = concentration of radionuclide i in edible portion of plant v (pCi/kg)
- d_i = deposition rate [pCi/(m^2·hr)]
- r = fraction of deposition retained on plant (unitless), taken to be 0.25 for sprinkler irrigation
- T_v = factor for the translocation of externally deposited radionuclide to edible parts of plants (unitless). Assumed to be independent of radionuclide and taken to be 1 for leafy vegetables and fresh forage, and 0.1 for all other produce, including grain.
- λ_{Ei} = effective removal constant of radionuclide i from plant (hr^{-1}) $\lambda_{Ei} = \lambda_i + \lambda_w$, where λ_w = weathering removal constant = 0.693/14 (day^{-1})
- t_e = time of above ground exposure of crop to contamination during growing season (hr)
- Y_v = plant yield [kg(wet weight)/m^2]
- B_{iv} = concentration factor for plant uptake of nuclide i to edible part of plant from soil [pCi/kg(wet weight) per pCi/kg (dry soil)]

t_b • time for buildup of radionuclide in soil (hr), taken to be 30 years for typical power reactor

P • soil "surface density" [kg(dry soil)/m^2]. Assuming a uniform mixing of all radionuclides in a plowlayer of 15 cm (6 in.) depth, P has a value of approximately 224 kg/m^2.

t_h • holdup time (hr^{-1}); the time interval between harvest to consumption of the food.

The deposition rate d_i from irrigation water is defined by the relation

$$d_i = C_{iw}\ I \text{ (water deposition)} \tag{2}$$

where

C_{iw} • concentration of radionuclide i in water used for irrigation (pCi/ℓ)

I • irrigation rate [ℓ/(m^2·hr)]; amount of water sprinkled on unit area of field in 1 hour.

The dose rate in mrem/yr to a particular organ r would then be given by Equation 3 for n radionuclides i via a particular vegetable pathway v:

$$R_{vr} = \sum_{i=1}^{n} C_{iv}\ U_v\ D_{ivr} \tag{3}$$

where

R_{vr} • the dose rate to organ r from all nuclides via pathway v (ingestion of a particular irrigated food)

C_{iv} • the concentration of nuclide i in the media of pathway v

U_v • usage: the intake rate of food v

D_{ivr} • a dose factor: a number specific to a given nuclide i, pathway v, and organ r which can be used to calculate radiation dose from the intake rate of that radionuclide. In this instance pathway v is ingestion and the dose factor has units of mrem/yr per pCi/yr ingested. (These factors are listed under the ARRRG program description in Appendix III-A, Part 1.)

III-A.3 Animal Products

The radionuclide concentration in an animal product such as meat, milk or eggs is dependent on the amount of contaminated feed or forage eaten by the animal and its uptake of contaminated water. The following equation describes this model for the concentration in animal products.[2]

$$C_{ia} = S_{ia} \left[C_{iF}\ Q_F + C_{iaw}\ Q_{aw} \right] \tag{4}$$

where

C_{ia} • concentration in aminal produce (pCi/ℓ) or (pCi/kg)

S_{ia} • transfer coefficient of radionuclide i from daily intake of animal to edible portion of animal product [pCi/ℓ (milk) per pCi/day] or [pCi/kg (animal product) per pCi/day]

C_{iF} • concentration of nuclide i in feed or forage (pCi/kg) calculated from Equation 1 above

9 1 1 8 9 1 1 4 5 9

Q_F • consumption rate of contaminated feed or forage by animal (kg/day)

C_{iaw} • concentration of nuclide i in water consumed by animals (pCi/ℓ); assumed usually to be equal to C_{iw}

Q_{aw} • consumption rate of contaminated water by animal (ℓ/day)

The second set of terms in the brackets in Equation 4 can be omitted if the animal does not drink contaminated water. Average consumption rates assumed for this study are listed in Table III-A-25.

TABLE III-A-25

ANIMAL CONSUMPTION RATES[2]

	QF Feed or Forage (kg/day)	QAW Water (l/day)
Milk cow	55 (pasture grass)	60
Beef cattle	68 (stored feed grain)	50
Pig	4.2 (stored feed grain)	10
Chicken	0.12 (grain)	0.3

The dose from the consumption of animal products is given by Equation 3 with C_{ia} substituted for C_{iv}.

For a cow grazing on fresh forage, t_e in Equation 1 is set equal to 720 hours (30 days), the typical time for a cow to return to a particular portion of the grazing site.

Values for the various plant concentration factors and animal product transfer coefficients for the elements considered are given in Table III-A-26. For the plant concentration factors Reference 2 was consulted and modified at times. Transfer coefficients were also taken from the literature where available for beef,[2] pork,[2] poultry,[2] eggs,[2,3] and milk.[4] The milk transfer coefficients of Reference 4 were reduced by a factor of one-half to account for average transfer of radionuclides from grass to milk via a cow, rather than maximum.

For the Hanford Waste Management Operations Environmental Impact Statement the contribution to the radiation doses to the Maximum Individual were estimated using the parameters listed in Table III-A-27. On infrequent occasions hay harvested from irrigated land is fed to milk cows causing traces of ^{65}Zn to appear for short periods of times in farm milk.

The dose to the total population in the vicinity of Hanford from irrigated foods was estimated as explained in the main text. It was assumed that a total of less than 2000 persons could be fed with the river-irrigated foods produced at the Ringold and Riverview areas. Since the average adult diet is generally about one-half of the Maximum Individual's diet, the man-rem dose to the population would be approximately numerically equal to the whole body dose (in mrem) to the maximum individual, that is

$$2000(\text{people}) \times 0.5(\text{diet}) \times 10^{-3}\left(\frac{\text{rem}}{\text{mrem}}\right) = 1.0$$

TABLE III-A-26

PLANT CONCENTRATION FACTORS AND ANIMAL PRODUCT TRANSFER COEFFICIENTS[(a)]

Element	B_{iv} Plant Soil (Dimensionless)	S_{ia} Egg/Feed (day/egg)	Milk/Feed (day/ℓ)	Beef/Feed (day/kg)	Pork/Feed (day/kg)	Poultry/Feed (day/kg)
H	0.2	1	0.01	1	1	1
C	5.5	1	0.0075	1.0	1	1
Na	0.05	0.01	0.025	0.05	0.1	0.01
P	1.1	0.1	0.012	0.033	0.54	0.19
Sc	0.0011	*	2.5×10^{-6}	*	*	*
Cr	0.00025	*	0.0011	*	*	*
Mn	0.029	0.005	0.00012	0.005	0.01	0.001
Fe	0.0004	0.005	0.0006	0.001	0.005	0.001
Co	0.0094	0.005	0.0005	0.001	0.005	0.001
Ni	0.019	0.005	0.0034	0.001	0.005	0.001
Cu	0.13	0.010	0.007	0.002	0.005	0.002
Zn	0.4	0.0002	0.02	0.002	0.005	0.002
Sr	0.2	0.007	0.001	0.002	0.008	0.0009
Y	0.0025	1×10^{-5}	1×10^{-5}	0.006	0.01	0.004
Zr	0.00017	6×10^{-5}	2.5×10^{-6}	0.0005	0.001	0.0001
Nb	0.0094	2×10^{-5}	0.0012	0.0005	0.001	0.0001
Mo	0.13	0.0070	0.0038	0.01	0.02	0.002
Tc	0.25	*	0.012	*	*	*
Ru	0.01	7×10^{-5}	5×10^{-7}	0.001	0.005	0.0003
Rh	0.13	7×10^{-5}	0.005	0.001	0.005	0.0003
Sn	0.0025	1×10^{-5}	0.0025	0.0025	0.005	0.002
Sb	0.011	*	0.00075	*	*	*
Te	1.3	0.007	0.0005	0.005	0.01	0.01
I	0.02	0.03	0.01	0.02	0.09	0.004
Cs	0.003	0.02	0.007	0.03	0.04	0.4
Ba	0.005	0.006	0.0003	0.0005	0.002	0.0005
La	0.0025	4×10^{-5}	2.5×10^{-6}	0.005	0.01	0.004
Ce	0.0005	5×10^{-5}	1×10^{-5}	0.001	0.005	0.0006
Pr	0.0025	4×10^{-5}	2.5×10^{-6}	0.005	0.01	0.004
Nd	0.0024	4×10^{-5}	2.5×10^{-6}	0.005	0.01	0.004
Pm	0.0025	4×10^{-5}	2.5×10^{-6}	0.005	0.01	0.004
Sm	0.0025	4×10^{-5}	2.5×10^{-6}	0.005	0.01	0.004
Eu	0.0025	4×10^{-5}	5.5×10^{-6}	0.005	0.01	0.004
U	0.0025	5×10^{-5}	0.0005	0.005	0.0001	0.004
Np	0.0025	5×10^{-5}	2.5×10^{-6}	0.005	0.0001	0.004
Pu	0.00025	5×10^{-5}	7.5×10^{-7}	0.005	0.0001	0.004
Am	0.00025	5×10^{-5}	2.5×10^{-6}	0.005	0.0001	0.004
Cm	0.0025	5×10^{-5}	2.5×10^{-6}	0.005	0.0001	0.004

*Value unknown or very small; assumed to be zero for calculations.
(a) For use in Equations 1 and 4.

TABLE III-A-27

FOOD INPUT WORKSHEET

REACTOR NAME HEIS - 100-N + 100-F + 300 A   DATE May 1974

TITLE Dose to Maximum Individual

FOOD TYPES	HOLDUP (day)	CONSUMPTION (kg/yr or ℓ/yr)	IRRIGATION RATE (ℓ/m²/mo)	YIELD (kg/m²)	GROWING PERIOD (day)
1. Leafy Vegetables	1	30 (b)	150	1.5	90
2. O.A.G.(a) Vegetables	1	30 (b)	160	0.7	60
3. Potatoes	10	110	180	4.0	90
4. Other Root Vegetables	1	72	150	5.0	90
5. Berries	1	30	150	2.7	60
6. Melons	1	40	150	0.8	90
7. Orchard Fruit	10	265	150	1.7	90
8. Wheat	10	80	0	0.72	90
9. Other Grain	1	8 (b)	150	1.4	90
10. Eggs	1	30	150	(0.84) (c)	90
11. Milk	1	274 (b)	0	(1.3)	30 (d)
12. Beef	15	40	140	(0.84)	90
13. Pork	15	40	140	(0.84)	90
14. Poultry	1	18	140	(0.84)	90

RIVER FLOW IN CFS 160,000   MIXING RATIO 1

RECONCENTRATION MODELS

☐ 1 Simplified theoretical model
VOLUME ______ ft^3 TURNOVER RATE ______ day^{-1}
MAKEUP FLOW ______ cfs   CYCLE TIME ______ hr

☐ 2 Empirical model
RECYCLE FRACTION ______   CYCLE TIME ______ hr

☒ 3 No reconcentration

NOTES:

(a) Other Above Ground
(b) During irrigation season only.
(c) () indicates yield of animal feed.
(d) Length of time before cow returns to same piece of pasture.

III-A, Part 2 REFERENCES

1. J. K. Soldat, et al., Models and Computer Codes for Evaluating Environmental Radiation Doses, BNWL-1754, Battelle, Pacific Northwest Laboratory, Richland WA, February 1974.

2. J. F. Fletcher and W. L. Dotson (compilers), HERMES - A Digital Computer Code for Estimating Regional Radiological Effects from the Nuclear Power Industry, HEDL-TME-71-168, Hanford Engineering Development Laboratory, Richland WA, 1971.

3. F. R. Mraz, et al., "Fission Product Metabolism in Hens and Transference to Eggs," Health Physics, vol. 10, pp. 777-782, 1964.

4. Y. C. Ng, et al., Prediction of the Maximum Dosage to Man from the Fallout of Nuclear Devices - IV, Handbook for Estimating the Maximum Internal Dose from Radionuclides Released to the Biosphere, UCRL-50163, Pt.IV. Lawrence Radiation Lab., Univ. of California, Livermore CA, 1968.

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APPENDIX III-B

DESCRIPTION OF MATHEMATICAL MODELS USED IN DOSE CALCULATIONS FOR ACCIDENTS

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III-B DESCRIPTION OF MATHEMATICAL MODELS USED IN DOSE CALCULATIONS FOR ACCIDENTS

This appendix describes mathematical models used to calculate external and internal doses from the accidental release of radionuclides from nuclear facilities.

III-B.1 Atmospheric Dispersion Models

The atmospheric dispersion of radionuclides can be described mathematically by a bivariate normal distribution model which has been in use at Hanford for many years. The standard deviations of the cloud concentration in the crosswind lateral and vertical directions can be estimated from any of the several methods in common use; i.e., Sutton's parameters, Hanford equations, or Pasquill's curves. Using this model, the air concentration at ground level is given by:

$$\chi = \frac{Q'}{\pi \sigma_y \sigma_z \bar{u}_h} \exp\left(-y^2/2\,\sigma_y^2 - h^2/2\,\sigma_z^2\right) \tag{1}$$

where:

χ = ground level air concentration at the coordinates x and y, Ci/m^3

x = downwind distance measured from point of release, meters

y = crosswind distance measured horizontally from centerline of cloud, meters

Q' = apparent rate of release at receptor, Ci/sec[(a)]

σ_y = crosswind lateral standard deviation of cloud concentration, m

σ_z = crosswind vertical standard deviation of cloud concentration, m

$\bar{u}_h$ = average wind speed at the height of release in direction of travel, m/sec

h = height of release, m

(a) apparent rate of release at receptor is the rate of release at the source corrected for radioactive decay during time of transport to receptor

III-B.1.1 Accidental Release

The time-integrated air concentration is convenient to use when calculating doses resulting from accidental releases of short duration. Also, use of the cloud centerline air concentration results in a maximum estimate of this quantity thereby maximizing the resultant dose. The centerline time-integrated air concentration is given by:

$$E_o = \frac{Q}{\pi \sigma_y \sigma_z \bar{u}_h} \exp\left(-h^2/2\sigma_z^2\right) \tag{2}$$

where:

E_o = time-integrated air concentration at ground level beneath the centerline of the cloud, $Ci \cdot sec/m^3$

Q = total release from source, curies.

The crosswind standard deviations, σ_y and σ_z, for stable atmospheric conditions are calculated by the Hanford model[1,2] as follows:

$$\sigma_y^2 = A\left[T - \alpha(1 - e^{-T/\alpha})\right] \qquad (3a)$$

$$\sigma_z^2 = a(1 - e^{-K^2T^2}) + bT \qquad (3b)$$

where: T • transport time from point of release to point of interest, sec

and: $A = c + d(\sigma_\theta \bar{u})$

$$\alpha = \frac{A}{2(\sigma_\theta \bar{u})}\,2$$

and a, b, c, d, k and $(\sigma_\theta \overline{u})$ are parameters describing the atmospheric condition. Table III-B-1 summarizes parameter values used in this study.

TABLE III-B-1

VALUES OF METEOROLOGICAL PARAMETERS FOR THE HANFORD MODEL

Parameter	Moderately Stable Conditions	Very Stable Conditions
a	97	34
b	0.33	0.025
c	13	13
d	230	230
k	2.5×10^{-4}	8.8×10^{-4}

MINIMUM VALUES OF $(\sigma_\theta \overline{u})$

Assumed Duration of Release, min	$(\sigma_\theta \overline{u})$
10	0.024
60	0.040
120	0.080
240	0.10
480	0.18

Crosswind standard deviations calculated for unstable and neutral conditions with Sutton's parameters are:

$$\sigma_y^2 = 0.5C_y^2\, x^{(2 - n)} \qquad (4a)$$

$$\sigma_z^2 = 0.5C_z^2\, x^{(2 - n)} \qquad (4b)$$

where:

n • atmospheric stability index

C_y • virtual diffusion parameter in the horizontal crosswind direction

C_z • virtual diffusion parameter in the vertical crosswind direction.

Representative values of the parameters n, C_y and C_z are tabulated in Table II-B-2. Numerical values of σ_y and σ_z in use at Hanford representative of Pasquill's curves are listed in Tables III-B-3 and III-B-4.

TABLE III-B-2

NUMERICAL VALUES OF ATMOSPHERIC DISPERSION PARAMETERS FOR NEUTRAL AND UNSTABLE ATMOSPHERES

Parameter	Release Level	Wind Speed	Unstable	Neutral
C_y	Ground	1 m/s	0.35	0.21
		5 m/s	0.30	0.15
		10 m/s	0.28	0.14
	Elevated	1 m/s	0.30	0.15
		5 m/s	0.26	0.12
		10 m/s	0.24	0.11
C_z	Ground	1 m/s	0.35	0.17
		5 m/s	0.30	0.14
		10 m/s	0.28	0.13
	Elevated	1 m/s	0.30	0.15
		5 m/s	0.26	0.12
		10 m/s	0.24	0.11
n			0.20	0.25

TABLE III-B-3

VALUES OF σ_y FOR PASQUILL STABILITY CATEGORIES

DISTANCE METERS	σ_y for Pasquill Type A	B	C	D	E	F
100	21	16	12	8.0	6.0	3.9
150	34	24	18	12	9.0	6.0
250	54	40	28	20	14	9.8
350	75	55	40	26	20	14
500	100	76	55	37	28	18
700	140	110	76	51	37	26
1,000	200	150	110	72	52	36
1,500	290	220	160	100	75	52
2,500	450	340	240	160	120	81
3,500	610	460	330	220	160	110
5,000	830	630	450	310	220	150
7,000	1,100	840	610	420	300	210
10,000	1,600	1,200	850	570	410	280
15,000	2,200	1,700	1,200	810	570	400
25,000	3,400	2,600	1,800	1,200	880	610
35,000	4,500	3,500	2,500	1,700	1,200	820
50,000	6,200	4,700	3,400	2,300	1,600	1,100
70,000	8,200	6,400	4,700	3,000	2,100	1,500
100,000	11,000	8,500	6,300	4,100	2,800	2,000

TABLE III-B-4

VALUES OF σ_z FOR PASQUILL STABILITY CATEGORIES

DISTANCE METERS	σ_z for Pasquill Type A	B	C	D	E	F
100	15	10	7.8	4.7	3.0	1.4
150	22	15	11	6.8	4.3	2.2
250	43	26	18	10	7.1	4.0
350	70	37	24	14	9.4	5.3
500	140	57	34	19	13	7.6
700	270	86	46	25	17	10
1,000	670	140	64	33	22	14
1,500	2,000	240	90	43	29	18
2,500	2,000	580	140	62	41	25
3,500	2,000	1,200	190	76	50	30
5,000	2,000	2,000	260	95	61	35
7,000	2,000	2,000	340	120	72	41
10,000	2,000	2,000	440	140	84	47
15,000	2,000	2,000	600	170	99	55
25,000	2,000	2,000	880	220	120	64
35,000	2,000	2,000	1,100	260	130	72
50,000	2,000	2,000	1,400	320	140	79
70,000	2,000	2,000	1,800	370	160	36
100,000	2,000	2,000	2,000	450	170	94

III-B.1.2 Chronic Release

Normal operations involving chronic low-level release rates usually require determination of average air concentrations within geometric sectors surrounding the facility. These average concentrations are determined by:

$$\bar{X}_{sect} = \frac{0.01\, Q' f_d}{w} \left(\frac{2}{\pi}\right)^{1/2} \sum_i \sum_j \frac{f_{ij} \exp\left[-h^2/2(\sigma_z^2)_{ij}\right]}{(\sigma_z)_{ij}(\bar{u}_h)_i} \qquad (5)$$

where terms not previously defined are:

- $\bar{\chi}_{sect}$ • sector average air concentration at ground, Ci/m^3
- w • sector width ($=2\pi x/n$), meters
- n • number of equal sized sectors in 360 degrees
- f_{ij} • joint frequency of occurrence release in sector for wind speed interval i and stability class j.

III-B.2 Whole Body Tissue Dose from Gamma Radiation

The basic equation for the external whole body tissue dose rate from a gamma emitting radionuclide present in the incremental volume of a cloud is:[3]

$$d_\gamma = K_k \frac{\chi B\ (\mu_k r)\ \exp\ (-\mu_k r)}{4\pi r^2}\ dxdydz \tag{6}$$

where:

- d_γ • incremental dose rate to tissue, (rad/sec)/(MeV/dis), from gamma radiation emitted from an incremental cloud volume, dx, dy, dz at a distance r meters from the point of interest
- χ • concentration in incremental cloud volume, Ci/m^3
- $B(\mu_k r)$ • dose buildup factor for air
- μ_k • total linear attenuation coefficient in air, m^{-1}, for photons with gamma energy in energy group k
- K_k • dose conversion factor, $(rad \cdot m^2)/(Ci \cdot sec)$ per MeV/disintegration.

$$K_k = \frac{3.70 \times 10^{10} \frac{dis}{Ci \cdot sec}\ 1.60 \times 10^{-6} \frac{erg}{MeV}\ 10^{-4} \frac{m^2}{cm^2}}{100 \frac{ergs}{g \cdot rad}} \left(\frac{\mu_a}{\rho}\right)_k = 0.0592 \left(\frac{\mu_a}{\rho}\right)_k$$

where:

- $\left(\frac{\mu_a}{\rho}\right)_k$ • mass absorption coefficient, cm^2/g in tissue for average gamma energy of energy group k.

A quadratic expression is used to calculate the dose buildup factor.

$$B(\mu_k r) = 1 + A_k \mu_k r = \alpha_k (\mu_k r)^2 \tag{7}$$

where:

A_k and α_k are constants empirically determined to fit buildup factor data of Berger.[4]

Since dose rate is a function of γ-ray energy, the gamma spectrum has been divided into energy groups. The incremental dose is calculated separately as a function of photon energy and integrated over the cloud volume to obtain dose rate factors for each energy group. The dose rate factors are coupled with radionuclide release rate data, duration of release, and site climatology data to calculate dose.

The beta dose calculation is considerably simpler than the gamma dose calculation. Because of the short range of beta particles in air, the radionuclide cloud may be assumed to be semi-infinite in dimension. With this assumption, the tissue beta dose is:[1]

$$D_d^\beta = 0.23\ \bar{E}_\beta\ \ Q(E/Q)\ (D_d/D_0) \qquad (8)$$

where:

D_d^β • beta dose at depth d in tissue, rads

$\bar{E}_\beta$ • average beta energy, MeV/dis

Q • quantity of radionuclide released, Ci

E • time-integrated air concentration, $Ci \cdot sec/m^3$

D_d/D_0 • depth dose correction factor.

The depth dose correction factors for several tissue depths have been calculated[5] and their energy dependence is illustrated in Figure III-B-1.

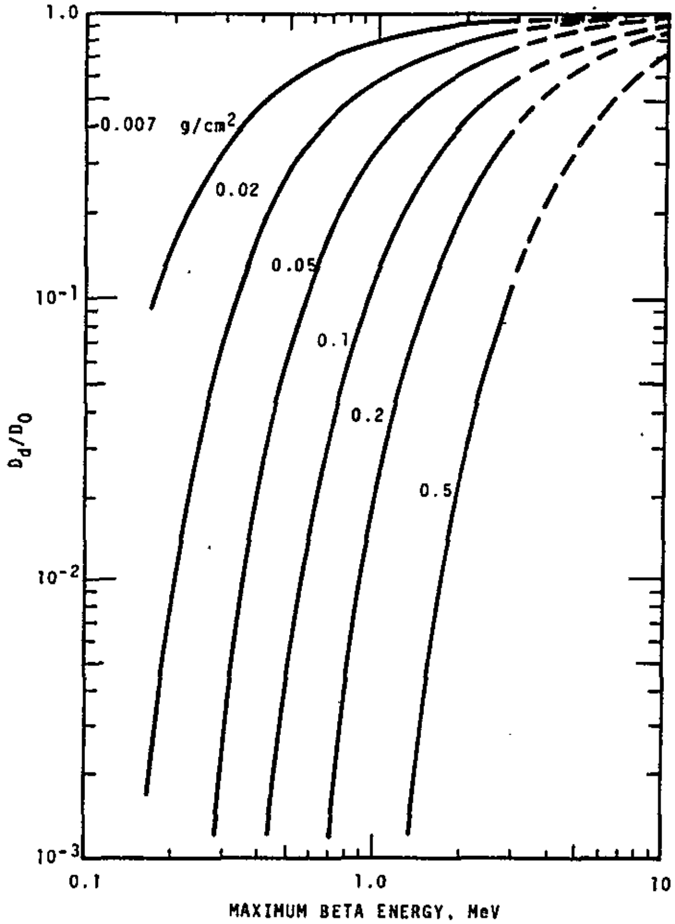

FIGURE III-B-1 RATIO OF DEPTH DOSE TO SURFACE DOSE AS A FUNCTION BETA ENERGY SPECTRA (for infinite plane source of infinite thickness and for allowed spectra)

III-B.3 Inhalation Dose Models

Two lung models have been recommended by the International Commission on Radiological Protection (ICRP). The initial lung model, recommended in ICRP Publication 2 and hereinafter referred to as the ILM, treats the inhaled material as either soluble or insoluble. When the inhaled material is soluble, the uptake by other organs is assumed to be essentially instantaneous. The more sophisticated lung model, recently recommended by ICRP Publication 19 and hereinafter referred to as the TGLM, treats the inhaled material in a more complex way. The derived equations for estimating the dose to organs other than the lung are considerably more complex than those for the ILM. A computer program has been developed for calculating the dose to lung and other organs using the TGLM.[6]

III-B.3.1 ILM

The dose to and organ of interest via inhalation using the ILM, from a radionuclide accidently released to the atmosphere, is given by:

$$D = f_a k P_s \left\{\left[1 - \exp(-\lambda_e t)\right]\right\}, \text{ rem}$$

$$P_s = bQ'\tau\,(E/Q) = bQ(E/Q), \ \mu\text{Ci}$$

$$D = b(f_a k)\, Q(E/Q) \left\{\left[1 - \exp(-\lambda_e t)\right]\right\}, \text{ rem} \qquad (9)$$

where:

D = dose to organ of interest delivered over time t, rem
f_a = fractional uptake, via inhalation by organ of interest
k = dose conversion factor for organ of interest, rem per µCi in organ
P_s = quantity inhaled, µCi
λ_e = effective elimination rate constant, d^{-1}
t = time following initial intake, d
b = ventilation rate for standard man, cm^3/sec
b = 350 cm^3/sec (8 hour working rates)
b = 230 cm^3/sec (24 hour daily rate)
Q' = atmospheric release rate, Ci/sec
τ = duration of release (exposure), sec
Q = quantity released, Ci
E/Q = time integrated air concentration normalized to quantity released, Ci-sec/m^3 per Ci.

The dose from inhalation during chronic atmospheric releases is given by:

$$D = f_a k \frac{P}{\lambda_e} \left\{\lambda_e t - \left[1 - \exp(-\lambda_e t)\right]\right\} \qquad (10)$$

where previously undefined terms are:

P = daily intake, µCi/day
P = $86400\, b\, \bar{X}_{sect}$.

When the chronic intake is interrupted at time, t_1 say, then the dose is determined by:

$$D = f_a k \frac{P}{\lambda_e} \left(\lambda_e t - \left\{\exp\left[-\lambda_e(t - t_1)\right]\right\}\left[1 - \exp(-\lambda_e t_1)\right]\right) \qquad (10a)$$

III-B.3.2 TGLM

The mathematical model for calculating the dose to an organ of interest via inhalation using the TGLM is considerably more complex than that utilized by the ILM. In the TGLM, the respiratory tract is divided into three regions, the nasopharyngeal (NP), the tracheobronchial (TB), and the pulmonary (P). The schematic representation of the respiratory tract used in the development of the mathematical model for the deposition and clearance of inhaled radionuclides is shown in Figure III-B-2. Deposition is assumed to vary with the aerodynamic properties of the aerosol distribution and is described by the three parameters D_3, D_4, and D_5. These parameters represent the fraction of the inhaled material initially deposited in the NP, TB and P regions, respectively. Each of the three regions of deposition are further subdivided into two or more subcompartments, each representing the fraction of material initially in a compartment that is subject to a certain clearance process. This fraction is represented by f_k, where k indicates the clearance pathway. For example, the quantity of material in the TB region cleared by process (c) is then represented by the produce $f_c D_4 Q_I$. Values of the (f_k) and the clearance half times T_k for each clearance process for the three solubility classes of aerosols used in the computer code are shown in Table III-B-5.[6] Values of the deposition fractions D_3, D_4, and D_5 as function of activity median aerodynamic diameter in the form of a graph have been published.[7]

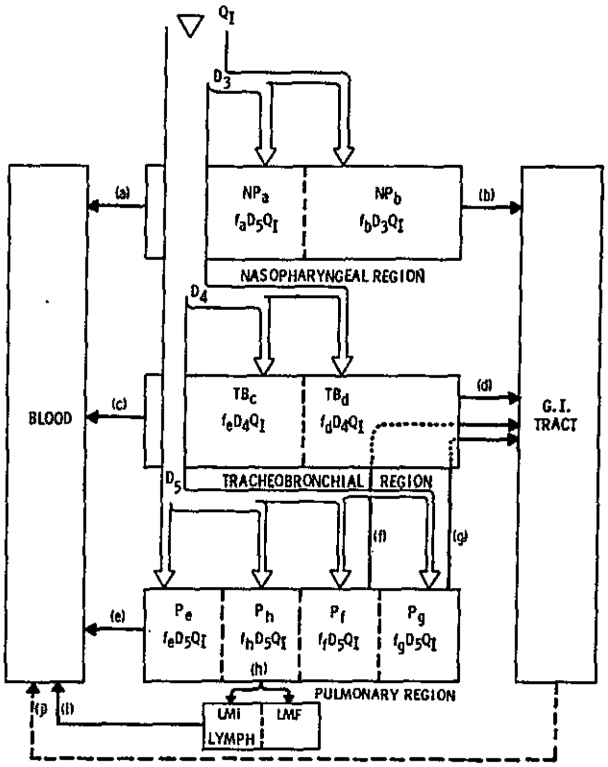

FIGURE III-B-2 SCHEMATIC DIAGRAM OF ICRP TASK GROUP LUNG MODEL

TABLE III-B-5

VALUES OF THE CLEARANCE PARAMETERS FOR THE TASK GROUP LUNG MODEL

COMPARTMENT		SOLUBILITY CLASS					
		D		W		Y	
	$k^{(a)}$	$T_k^{(b)}$	$f_k^{(c)}$	T_k	f_k	T_k	f_k
NP	a	0.01	0.5	0.01	0.1	0.01	0.01
	b	0.01	0.5	0.40	0.9	0.4	0.99
TB	c	0.01	0.95	0.01	0.5	0.01	0.01
	d	0.2	0.05	0.2	0.5	0.2	0.99
P	e	0.5	0.8	50	0.15	500	0.05
	f	n.a.	n.a.	1	0.4	1	0.4
	g	n.a	n.a.	50	0.4	500	0.4
	h	0.5	0.2	50	0.05	500	0.15
L	i	0.5	1	50	1	1000	0.9

(a) Metabolic pathways from lung.

(b) Removal half time in days from compartment via pathway k.

(c) Fraction removed from compartment via pathway k.

The respiratory tract model was incorporated into the simple metabolic model.[8] Transport of the radionuclides from the respiratory tract, lymph, and G.I. tract to organs and tissues, where significant accumulations of the inhaled activity occur, is assumed to take place via the blood. The report of the Task Group[7] describes in some detail this translocation of the activity from the respiratory tract and lymph to the blood. Of the material clearing from the respiratory tract through the G.I. tract, a constant fraction is assumed to be taken up by the blood. Uptake by the nth organ or tissue is assumed to be a constant fraction of the amount entering the blood stream at any time. Once in the nth organ, the activity is assumed to clear the organ and the body at a constant rate.

The dose commitment for both individual and population inhalation exposure was based on an inhalation time equivalent to either the duration of the release, the accidental releases or one year for a chronic release. In this study, two dose commitment values are usually calculated - one corresponding to the dose delivered in the first year following exposure and the other corresponding to the dose delivered over a 50-year interval following exposure.

Notation for the equations found in this section is as follows:

$D_{1n}(T_1)$ is the dose equivalent in rem received by the nth organ or tissue by time T_1 during continuous inhalation of a radioactive aerosol.

$D_{2n}(T_2)$ is the dose equivalent in rem received by the nth organ or tissue by time T_2 following the termination of continuous inhalation of a radioactive aerosol.

$Q_{1n}(T_1)$ is the quantity of radioactive material in μCi present in the nth organ or tissue as a function of time during continuous inhalation of a radioactive aerosol.

$Q_{2n}(T_2)$ is the quantity of radioactive material in μCi present in the nth organ or tissue following the termination of continuous inhalation of a radioactive aerosol.

E_n is the effective absorbed energy per disintegration in $\frac{\text{MeV·rem}}{\text{dis·rad}}$ for the nth organ or tissue.

M_n is the mass in grams of the nth organ or tissue over which the dose is to be averaged.

λ_k^b is the biological removal rate constant for the kth subcompartment of the respiratory tract in seconds.

λ is the radiological decay constant of the nuclide of interest in seconds.

λ_k is the total removal rate constant for the kth subcompartment of the respiratory tract in seconds and equals $\lambda_k^b + \lambda$.

λ_n^b is the biological removal rate constant for the nth organ or tissue in seconds.

λ_n is the total effective removal rate constant for the nth organ or tissue in seconds and equals $\lambda_n^b + \lambda$.

f_2' is the fraction of material in the blood that reaches the organ or tissue of interest.

f_1 is the fraction of material in the G.I. tract that reaches the blood.

P_o is the rate at which the radioactive aerosol is inhaled in μCi/sec.

f_k is the fraction of the material in a deposition region, NP, etc., that clears by the kth pathway.

D_3 is the fraction of the material inhaled deposited in the NP region.

D_4 is the fraction of the material inhaled deposited in the TB region.

D_5 is the fraction of the material inhaled deposited in the P region.

T_1 is the total uptake time in seconds.

T_2 is the time following termination of uptake.

The development of the equations to describe the lung clearance model was divided into two parts. The first part is concerned with describing the quantity present and the dose to the respiratory tract subcompartments and other organs during the inhalation of radionuclides. The second part, requiring a different set of equations, describes the burdens in and the dose to the organs or tissues for a contiguous period of time following the termination of uptake.

During uptake, the equations for computing the quantity of radionuclide in the eight subcompartments of the respiratory tract have the form:

$$Q_{1Pe}(t) = f_e\, D_5\, P_o \frac{(1-e^{-\lambda_e T_1})}{\lambda_e} \tag{11}$$

The equations for the removable quantity in the lymph are complicated by the fact that both equal and unequal rates for transfer paths into and out of the lympth are involved. This is due to the dependence of transfer rate upon the solubility class of the radionuclide. Thus, two equations are needed to compute the quantity in the lymph.

For the case $\lambda_h \neq \lambda_i$, i.e., class y solubility in the current version of the model:

$$Q_{LMi}(t) = \frac{\lambda_h^b F_i F_h P_o D_5}{\lambda_h} \left[\frac{(1-e^{-\lambda_i t})}{\lambda_i} - \frac{(e^{-\lambda_i t}-e^{-\lambda_h t})}{\lambda_h-\lambda_i}\right] \tag{12}$$

and for the case $\lambda_h=\lambda_i$, i.e., class D and W in the current version of the model:

$$Q_{LMi}(t) = \frac{\lambda_h^b f_i f_h P_o D_5}{\lambda_h} \left[\frac{(1-e^{-\lambda_i t})}{\lambda_i} - te^{-\lambda_i t}\right] \tag{13}$$

With the preceding equations, the equations describing the quantity of radionuclide in an organ as a function of time during uptake can be derived by:

$$Q_{1n}(t) = f_2' P_o \sum_{j=a}^{g} C_j \left[\frac{(1-e^{-\lambda_n t})}{\lambda_n} - \frac{(e^{-\lambda_n t}-e^{-\lambda_j t})}{(\lambda_j-\lambda_n)}\right] + L \tag{14}$$

where:

L = the contribution to the organ burden from material passing through the lumph,

and:

$C_a = \lambda_a^b f_a\, D_3/\lambda_a$

$C_b = \lambda_b^b f_b\, D_3 f_1/\lambda_b$

$$C_c = \lambda_c^b f_c \; D_4/\lambda_c$$

$$C_d = \lambda_d^b f_d \; D_4 f_1/\lambda_d$$

$$C_e = \lambda_e^b f_e \; D_5/\lambda_e$$

$$C_f = \lambda_f^b f_f \; D_5 f_1/\lambda_f$$

$$C_g = \lambda_g^b f_g \; D_5 f_1/\lambda_g$$

The lymph pathway contributions to the organ burden for the two situations are calculated as follows:

for $\lambda_h \neq \lambda_i$:

$$L = f_2' C_h \left\{ \frac{1}{\lambda_i} \left[\frac{(1-e^{-\lambda_n t})}{\lambda_n} - \frac{(e^{-\lambda_n t}-e^{-\lambda_i t})}{(\lambda_i-\lambda_n)} \right] - \frac{1}{(\lambda_i-\lambda_n)} \left[\frac{(e^{-\lambda_n t}-e^{-\lambda_i t})}{(\lambda_i-\lambda_n)} - \frac{(e^{-\lambda_n t}-e^{-\lambda_h t})}{(\lambda_h-\lambda_n)} \right] \right\} \quad (15)$$

where: $C_h = \dfrac{\lambda_i \lambda_h f_i f_h D_5}{\lambda_h}$

for $\lambda_h = \lambda_i$:

$$L = f_2' C_h \left\{ \frac{1}{\lambda_i} \left[\frac{(1-e^{-\lambda_n t})}{\lambda_i} \right] - \frac{(e^{-\lambda_n t}-e^{-\lambda_i t})}{(\lambda_i-\lambda_n)} - \frac{(e^{-\lambda_n t}-e^{-\lambda_i t}) \quad (\lambda_i-\lambda_n) \quad (t+1)}{(\lambda_i-\lambda_n)^2} \right\} \quad (16)$$

The calculation of the dose equivalents received by the tissues at risk are based on the following:

$$D_{1n}(t) = \frac{5.92 \times 10^{-4} E_n}{M_n} \int_0^t Q_{1n}(\tau) d\tau \quad (17)$$

where

$$5.92 \times 10^{-4} = 3.7 \times 10^4 \left(\frac{\text{dis/sec}}{\mu\text{Ci}}\right) 1.6 \times 10^{-6} \left(\frac{\text{ergs}}{\text{MeV}}\right) 10^{-2} \left(\frac{\text{rads}}{\text{erg/g}}\right).$$

The dose computations for the pulmonary lung and the nth organ or tissue at the end of inhalation uptake for a time T_1 are made using the following equations:

for the pulmonary lung:

$$D_{1p}(T_1) = \frac{5.92 \times 10^{-4} E_p}{M_p} P_o D_5 \sum_{j=e}^{h} \frac{f_j}{\lambda_j} \left(T_1 - \frac{1-e^{-\lambda_j T_1}}{\lambda_j} \right) \quad (18)$$

where M_p is the mass of the lung in grams

for the nth organ or tissue when $\lambda_h \neq \lambda_i$:

$$D_{1n}=5.92 \times 10^{-4}\frac{E_nP_of_2'}{M_n}\left\{\sum_{j=a}^{g} C_j\left[T_1 - A_n - \left(\frac{A_n - A_j}{\lambda_j - \lambda_n}\right)\right]\right.$$

$$\left. + \frac{C_h}{\lambda_i}\left[\frac{T_1 - A_n}{\lambda_n} - \frac{A_n - A_i}{(\lambda_i - \lambda_n)}\right] - \frac{C_h}{(\lambda_h - \lambda_i)}\left[\frac{A_n - A_i}{(\lambda_i - \lambda_n)} - \frac{A_n - A_h}{\lambda_h - \lambda_n}\right]\right\} \tag{19}$$

where:

$$A_n = \frac{1 - \exp(-\lambda_nT_1)}{\lambda_n}$$

$$A_j = \frac{1 - \exp(-\lambda_jT_1)}{\lambda_j}$$

$$A_i = \frac{1 - \exp(-\lambda_iT_1)}{\lambda_i}$$

$$A_h = \frac{1 - \exp(-\lambda_hT_1)}{\lambda_h}$$

for the nth organ or tissue when $\lambda_h=\lambda_i$:

$$D_n(T_1) = 5.92 \times 10^{-4}\frac{E_nP_of_2'}{M_n}\left(\sum_{j=a}^{g} C_j\left(\frac{T_1 - A_n}{\lambda_n} - \frac{A_n - A_j}{\lambda_j - \lambda_n}\right) + \frac{C_h}{\lambda_i}\left(\frac{T_1 - A_n}{\lambda_n} - \frac{A_n - A_i}{\lambda_i - \lambda_n}\right) - \frac{C_h}{(\lambda_i - \lambda_n)^2}\left\{A_i - A_n\right.\right.$$

$$\left.\left. + \frac{(\lambda_i - \lambda_n)}{\lambda_i^2}\left[1 - (\lambda_iT_1 + 1)\, e^{-\lambda_iT_1}\right]\right\}\right) \tag{20}$$

where C_j and C_h are as previously defined.

Now for the time following termination of uptake, the equations used to calculate the respiratory tract burden and the other organ or tissue burdens become:

$$Q_{2j}(T_2) = Q_{1j}(T_1)e^{-\lambda_jT_2} \tag{21}$$

where: $Q_{2j}(T_2)$ is the respiratory tract subcompartment burden at a time T_2 following the termination of inhalation uptake.

$Q_{1j}(T_1)$ is the respiratory tract subcompartment burden at the end of inhalation uptake for a time T_1.

For the burden in the nth organ when $\lambda_h \neq \lambda_i$:

$$Q_{2n}(T_2) = Q_{1n}(T_1)e^{-\lambda nT2} + f_2'\lambda_i^b\, Q_{1LMi}(T_1)\,\frac{(e^{-\lambda iT2} - e^{-\lambda nT2})}{(\lambda_n - \lambda_i)}$$

$$+ f_2'\left\{\sum_{j=a}^{g}\frac{C_j'}{(\lambda_j - \lambda_n)}(e^{-\lambda nT2} - e^{-\lambda jT2}) + C_h'\left[\frac{(e^{-\lambda nT2} - e^{-\lambda iT2})}{(\lambda_i - \lambda_n)} - \frac{(e^{-\lambda_nT2} - e^{-\lambda_hT2})}{(\lambda_h - \lambda_n)}\right]\right\} \tag{22}$$

where:

$$C_a' = \lambda_a^b Q_{1a}(T_1)$$

$$C_b' = \lambda_b^b Q_{1b}(T_1) f_1$$

$$C_c' = \lambda_c^b Q_{1c}(T_1)$$

$$C_d' = \lambda_d^b Q_{1d}(T_1) f_1$$

$$C_e' = \lambda_e^b Q_{1e}(T_1)$$

$$C_f' = \lambda_f^b Q_{1f}(T_1) f_1$$

$$C_g' = \lambda_g^b Q_{1g}(T_1) f_1$$

$$C_h' = \lambda_i^b Q_{1h}(T_1)/(\lambda_h - \lambda_i)$$

For the burden in the nth organ when $\lambda_h = \lambda_i$:

$$Q_{2n}(T_2) = Q_{1n}(T_1)e^{-\lambda_n T_2} = f_2' \lambda_i^b Q_{1LMi}(T_1)\frac{(e^{-\lambda_i T_2} - e^{-\lambda_n T_2})}{(\lambda_n - \lambda_i)}$$
$$+ f_2' \left(\sum_{j=a}^{g} \frac{C_j'}{(\lambda_j - \lambda_n)} (e^{-\lambda_n T_2} - e^{-\lambda_j T_2}) \right.$$
$$\left. + \frac{C_h'}{(\lambda_i - \lambda_n)} \left\{ e^{-\lambda_n T_2} - e^{-\lambda_i T_2} \left[(\lambda_i - \lambda_n) T_2 - 1 \right] \right\} \right) \qquad (23)$$

The effective total dose to the pulmonary lung due to inhalation uptake for a time T_1 followed by a period of no additional uptake for a time T_2 is computed using the following equation:

$$D_{1p}(T_2) = 5.92 \times 10^{-4} E_p P_o \left[\sum_{j=e}^{h} \frac{f_j D_5}{\lambda_j^2} (1 - e^{-\lambda_j T_1}) (1 - e^{-\lambda_j T_2}) \right] + D_{1p}(T_1) \qquad (24)$$

where: $D_{1p}(T_1)$ is the effective dose to the pulmonary lung during the uptake period.

Total effective dose to the nth organ as a result of inhalation uptake for a time T_1 followed by a period of no additional uptake for a time T_2 is computed using the equation that follows:

$$D_{2n}(T_2) = 5.92 \times 10^{-4} \frac{E_n}{M_n} \left(Q_{1n}(T_1) B_n + f_2' \left\{ \sum_{j=a}^{h} \frac{\lambda_j^b C_j'}{(\lambda_j - \lambda_n)} (B_n - B_j) \right. \right.$$
$$+ \frac{\lambda_i^b Q_{1LMi}(T_1)}{\lambda_n} \left[T_2 - B_n + D_{1n}(T_1) \right]$$
$$\left. \left. + C_h' \left(\frac{B_n - B_i}{\lambda_i - \lambda_n} - Z \right) \right\} \right) \qquad (25)$$

where:

$$Z = \frac{B_n - B_h}{\lambda_h - \lambda_i} \qquad \text{when } \lambda_i \neq \lambda_h$$

or:

$$Z = \frac{B_i}{\lambda_i}(\lambda_i T+1) \qquad \text{when } \lambda_i = \lambda_h$$

and:

$$B_n = \frac{1 - e^{-\lambda_n T_2}}{\lambda_n}$$

$$B_h = \frac{1 - e^{-\lambda_h T_2}}{\lambda_h}$$

$$B_i = \frac{1 - e^{-\lambda_i T_2}}{\lambda_i}$$

$$B_j = \frac{1 - e^{-\lambda_j T2}}{\lambda_j}$$

In addition, the equation for Q_{1n} is dependent on whether $\lambda_i = \lambda_h$ or not, so the choice of equations for the burden and dose computation must be consistent throughout.

III-B.4 Population Doses

The population dose from accidental releases is calculated for selected organs of reference from both external radiation and internal deposition resulting from inhalation. This calculation presumes the 1973 population distribution described in Appendix II.3-A.

Population dose for an accidental release is calculated by combining the dose to an individual for each sector as a function of distance, using the joint frequency distribution of wind speed and direction versus atmospheric stability as a probability function. In other words, the joint frequency distribution is assumed to describe the probability that an individual at a particular distance from the point of release in a specified sector will be exposed to the plume. The population dose then can be described by:

$$D_p^n = \sum_{r,k} f_{(i,j,k)} D^n_{(i,j,r)} \rho_{(r,k)} \text{ man-rem} \qquad (26)$$

where:

D_p^n = population dose with organ n as the organ of reference, man-rem

$f_{(i,j,k)}$ = joint frequency distribution describing fraction of time that wind blows within wind speed interval i, during atmospheric stability class, j in an angular sector, k

$D^n_{(i,j,r)}$ = dose to an individual at a downwind distance, r with organ n as the organ of reference, rem

$\rho_{(r,k)}$ = population density at radial distance, r in sector, k.

The 1973 population distribution centered on the 200 Area facilities was used to calculate population doses. The joint frequency distribution used was for the Hanford Meteorological Station as described in Section II. The dose was calculated to an individual at the midpoint of each annular sector for each of several organs of reference. The population dose for the population out to 50 miles from either area was then calculated using Equation 26 with appropriate values of r and k for annular sectors.

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APPENDIX III-C

ACCIDENT ESTIMATION TECHNIQUES

III-C ACCIDENT ESTIMATION TECHNIQUES

Evaluating the consequences of accidents requires an integration of many scientific disciplines. Once an accident is postulated, the amount and form of material which might be released must be characterized and the resulting environmental consequences quantified.

Since accidents are unique occurrences, estimating fractions of the material released to the environment is always an exercise in judgment. At Hanford, many experimental studies on release fractions for a variety of materials, under a variety of environmental conditions have been performed.[1-9] These studies of the behavior or characteristics of various materials containing radionuclides under various conditions (heating, aging, etc.) were appropriately modified for use in the analyses to reflect differences in conditions and source materials. Where possible, release values bracketing the postulated accident conditions were considered and technical judgment applied to obtain a "reasonable but larger than anticipated" inventory release value. When no data existed, an estimate was made using engineering principles and the known characteristics of the physical form of the material.

III-C.1 Calculation of Doses from Atmospheric Releases

The environmental consequences of the accidental release of radionuclides to the atmosphere which might result from each postulated accident were evaluated for exposure of people to the airborne plume. Atmospheric dispersion of the released radionuclides is described in this analysis by a bivariate normal distribution model. To calculate the resulting doses to individuals, a moderately stable atmosphere was assumed to exist throughout the course of the accidental release. A windspeed of ten meters per second (22 mph) was assumed for those accidents which postulate a release based on resuspension of ground deposited contaminants; otherwise, a one meter per second windspeed was used. Population dose calculations were based on sector average atmospheric dispersion formulae using joint frequency distributions of wind velocity and atmospheric stability characteristic of Hanford areas.

Dose calculations were made for both external exposure from submersion in the passing cloud and internal exposure from inhalation. The resulting external exposure was calculated at a depth of five centimeters, corresponding to whole body dose. Doses resulting from possible inhalation were calculated for several organs of reference including whole body, lungs, bone, and thyroid. The material inhaled was considered insoluble when calculating lung dose, and soluble when calculating dose to other organs of reference. The more recent lung model of the International Commission on Radiation Protection Task Group (TGLM) was used to calculate doses to individuals from inhalation.

Resulting population doses were estimated by calculating the dose to an individual at the sector center of several annular rings centered on either the 200 or 300 Areas. Every individual in the population within each annular sector was assumed to receive the same dose as the individual located at the sector center. The product of dose, annular sector population, and percentage of time the wind blew toward each sector was then compiled to give population dose in man-rems. (The models used in this study are discussed in Appendix III-B.)

III-C.2 Liquid Release Calculation

The movement of liquid released to the ground as a result of postulated accidents is important in the evaluation of environmental consequences. The movement of solutions of radioactive liquid waste through porous media systems under a variety of conditions was estimated using the PERCOL model.[10] This model determines concentration changes on the basis of chemical thermodynamic equilibria between the porous media and solution systems. In soils from the Hanford Reservation studied in experimental columns, the effects of ion exchange, sorption, dissolution and precipitation are dominant over the effects of diffusion and dispersion. Therefore, diffusion and dispersion are neglected in this model, but are included in the more refined multidimensional transport model. Assumptions used in PERCOL are:

- Dispersion, diffusion and evaporation are neglected.
- Seepage velocity is slow enough for sorption and chemical equilibrium to be attained.
- Cation exchange capacity is constant for each porous medium type.
- Binary equations approximate the complex cation exchange in porous media.
- Equilibrium states are path independent.
- Anion exchange is negligible.

- Limestone and gypsum are considered to be the only slightly soluble salts present and their solubility is assumed to be that of the crystalline form.
- Undissociated calcium sulfate is the only complex ion formed.
- Activity coefficients follow the extended Debye-Huckel theory.
- Uniform moisture content is present.
- Reactions of microions are determined by the macroions present as described by factorial design regression coefficients.

The formulation and parameters used to calculate radiation doses to residents of the Hanford vicinity from postulated accidental releases of radioactive material to surface and groundwater are incorporated in a multicomponent computer model. The pertinent codes in this model are ARRRG and FOOD. Although originally designed for annual doses from chronic releases, modification of the input parameters such as exposure hours, dilution in receiving waters, etc., allows calculation of internal and external doses from acute exposure to radionuclides in the environment. Excerpts from a complete description[11] of the model and computation codes are given in Appendix III-A. These codes represent a simplified version in an interactive computer language of the complex codes developed for ERDA's Year-2000 studies.[12,13]

Equations and parameters required for calculation of internal radiation doses from ingested radionuclides were given by the ICRP.[14] The equations used to calculate doses from external exposure to water and ground deposits may be found in Reference 15.

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APPENDIX III-D

RADIONUCLIDE INVENTORY OF HIGH-LEVEL WASTE IN WASTE TANK

APPENDIX III-D

RADIONUCLIDE INVENTORY OF HIGH-LEVEL WASTE IN WASTE TANK

III-D RADIONUCLIDE INVENTORY OF HIGH-LEVEL WASTE IN WASTE TANK

Included here are Tables showing the radionuclide inventories for a million-gallon waste storage tank that were used in the Accident Analysis (Volume 1, Section III.2) of this Environmental Impact Statement.

The waste tank is assumed to be filled over a 15-month period with waste from 2200 US tons of 0.95% of ^{235}U N Reactor fuel irradiated to 1380 MWd/T. The waste enters the tank after 200 days of cooling and contains no xenon or krypton, 0.1% of the uranium and plutonium, 10% of the neptunium, and 20% of the iodine in the fuel. In this inventory, all the cesium and strontium are assumed to remain in the waste with no B Plant processing. In this respect, the waste is atypical because B Plant processing usually removes most of the cesium and strontium.

Inventories are presented for the fission products and actinides from the time of filling of the tank to 100,000,000-yr cooling in the following order:

Table III-D-1 Weight Inventory by Nuclide, Grams
Table III-D-2 Radioactivity by Nuclide, Curies
Table III-D-3 Thermal Power by Nuclide, Watts

In reading the tables, the following interpretations are required:

CHARGE: value per ton of waste entering the tank
SEPARATION: total value at time tank is completely filled.

TABLE III-D-1 WEIGHT INVENTORY BY NUCLIDE, GRAMS

N REACTOR .947 ENRICHED PROPERTIES OF COLLECTED WASTE

POWER= 10.00MW, BURNUP= 1380.MWD, FLUX= 2.17E+13N/CM**2-SEC

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = 6200 TONS .947 ENR N REACTOR WASTE

	CHARGE	SEPARATION	1.0E+00YR	2.0E+00YR	3.0E+00YR	5.0E+00YR	1.0E+01YR	1.5E+01YR	2.0E+01YR	3.0E+01YR	5.0E+01YR	1.0E+02YR
H 3	2.71E-03	5.75E+00	5.44E+00	5.14E+00	4.86E+00	4.34E+00	3.28E+00	2.47E+00	1.86E+00	1.06E+00	3.44E-01	2.06E-02
GE 72	1.29E-04	2.84E-01	2.84E-01	2.84E-01	2.84E-01	2.84E-01	2.84E-01	2.84E-01	2.84E-01	2.84E-01	2.84E-01	2.84E-01
GE 73	5.18E-04	1.14E+00	1.14E+00	1.14E+00	1.14E+00	1.14E+00	1.14E+00	1.14E+00	1.14E+00	1.14E+00	1.14E+00	1.14E+00
GE 74	1.74E-03	3.83E+00	3.83E+00	3.83E+00	3.83E+00	3.83E+00	3.83E+00	3.83E+00	3.83E+00	3.83E+00	3.83E+00	3.83E+00
AS 75	3.47E-03	7.63E+00	7.63E+00	7.63E+00	7.63E+00	7.63E+00	7.63E+00	7.63E+00	7.63E+00	7.63E+00	7.63E+00	7.63E+00
GE 76	1.13E-02	2.48E+01	2.48E+01	2.48E+01	2.48E+01	2.48E+01	2.48E+01	2.48E+01	2.48E+01	2.48E+01	2.48E+01	2.48E+01
SE 76	4.84E-06	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.06E-02
SE 77	3.82E-02	8.41E+01	8.41E+01	8.41E+01	8.41E+01	8.41E+01	8.41E+01	8.41E+01	8.41E+01	8.41E+01	8.41E+01	8.41E+01
SE 78	9.65E-02	2.12E+02	2.12E+02	2.12E+02	2.12E+02	2.12E+02	2.12E+02	2.12E+02	2.12E+02	2.12E+02	2.12E+02	2.12E+02
SE 79	2.55E-01	5.61E+02	5.61E+02	5.61E+02	5.61E+02	5.61E+02	5.61E+02	5.61E+02	5.61E+02	5.61E+02	5.61E+02	5.61E+02
BR 79	2.31E-05	5.45E-02	6.05E-02	6.65E-02	7.24E-02	8.44E-02	1.14E-01	1.44E-01	1.74E-01	2.34E-01	3.54E-01	6.53E-01
SE 80	4.26E-01	9.38E+02	9.38E+02	9.38E+02	9.38E+02	9.38E+02	9.38E+02	9.38E+02	9.38E+02	9.38E+02	9.38E+02	9.38E+02
BR 81	6.96E-01	1.53E+03	1.53E+03	1.53E+03	1.53E+03	1.53E+03	1.53E+03	1.53E+03	1.53E+03	1.53E+03	1.53E+03	1.53E+03
SE 82	1.51E+00	3.32E+03	3.32E+03	3.32E+03	3.32E+03	3.32E+03	3.32E+03	3.32E+03	3.32E+03	3.32E+03	3.32E+03	3.32E+03
RB 85	4.50E+00	9.90E+03	9.90E+03	9.90E+03	9.90E+03	9.90E+03	9.90E+03	9.90E+03	9.90E+03	9.90E+03	9.90E+03	9.90E+03
SR 86	7.25E-04	1.60E+00	1.60E+00	1.60E+00	1.60E+00	1.60E+00	1.60E+00	1.60E+00	1.60E+00	1.60E+00	1.60E+00	1.60E+00
RB 87	1.18E+01	2.61E+04	2.61E+04	2.61E+04	2.61E+04	2.61E+04	2.61E+04	2.61E+04	2.61E+04	2.61E+04	2.61E+04	2.61E+04
SR 87	3.42E-08	7.55E-05	7.59E-05	7.63E-05	7.66E-05	7.74E-05	7.92E-05	8.10E-05	8.28E-05	8.64E-05	9.36E-05	1.12E-04
SR 88	1.71E+01	3.75E+04	3.75E+04	3.75E+04	3.75E+04	3.75E+04	3.75E+04	3.75E+04	3.75E+04	3.75E+04	3.75E+04	3.75E+04
SR 89	7.14E-01	2.63E+02	2.02E+00	1.56E-02	1.20E-04	7.08E-09	1.91E-19	5.14E-30	1.38E-40	1.00E-61	0.	0.
Y 89	2.26E+01	5.09E+04	5.12E+04	5.12E+04	5.12E+04	5.12E+04	5.12E+04	5.12E+04	5.12E+04	5.12E+04	5.12E+04	5.12E+04
SR 90	2.75E+01	5.96E+04	5.81E+04	5.67E+04	5.53E+04	5.27E+04	4.66E+04	4.12E+04	3.64E+04	2.84E+04	1.74E+04	5.06E+03
Y 90	7.15E-03	1.56E+01	1.51E+01	1.47E+01	1.44E+01	1.37E+01	1.21E+01	1.07E+01	9.46E+00	7.39E+00	4.51E+00	1.31E+00
ZR 90	5.07E-01	2.03E+03	3.48E+03	4.90E+03	6.26E+03	8.94E+03	1.51E+04	2.05E+04	2.52E+04	3.32E+04	4.43E+04	5.66E+04
Y 91	1.35E+00	5.58E+02	7.54E+00	1.02E-01	1.37E-03	2.51E-07	1.13E-16	5.06E-26	2.28E-35	4.59E-54	0.	0.
ZR 91	2.84E+01	6.49E+04	6.54E+04	6.54E+04	6.54E+04	6.54E+04	6.54E+04	6.54E+04	6.54E+04	6.54E+04	6.54E+04	6.54E+04
ZR 92	3.12E+01	6.86E+04	6.86E+04	6.86E+04	6.86E+04	6.86E+04	6.86E+04	6.86E+04	6.86E+04	6.86E+04	6.86E+04	6.86E+04
ZR 93	3.42E+01	7.52E+04	7.52E+04	7.52E+04	7.52E+04	7.52E+04	7.52E+04	7.52E+04	7.52E+04	7.52E+04	7.52E+04	7.52E+04
NB 93M	1.15E-05	4.54E-02	7.70E-02	1.07E-01	1.36E-01	1.89E-01	2.99E-01	3.85E-01	4.52E-01	5.44E-01	6.32E-01	6.78E-01
NB 93	2.23E-07	1.70E-03	4.82E-03	9.52E-03	1.57E-02	3.23E-02	9.50E-02	1.83E-01	2.90E-01	5.46E-01	1.15E+00	2.84E+00
ZR 94	3.50E+01	7.70E+04	7.70E+04	7.70E+04	7.70E+04	7.70E+04	7.70E+04	7.70E+04	7.70E+04	7.70E+04	7.70E+04	7.70E+04
ZR 95	2.15E+00	9.83E+02	2.00E+01	4.08E-01	8.30E-03	3.44E-06	1.20E-14	4.22E-23	1.48E-31	1.81E-48	0.	0.
NB 95M	2.64E-03	1.25E+00	2.45E-02	4.99E-04	1.02E-05	4.21E-09	1.48E-17	5.16E-26	1.81E-34	2.22E-51	0.	0.
NB 95	2.25E+00	1.06E+03	2.39E+01	4.88E-01	9.94E-03	4.02E-06	1.41E-14	4.93E-23	1.72E-31	2.11E-48	0.	0.
MO 95	3.11E+01	7.61E+04	7.81E+04	7.81E+04	7.81E+04	7.81E+04	7.81E+04	7.81E+04	7.81E+04	7.81E+04	7.81E+04	7.81E+04
ZR 96	3.63E+01	7.98E+04	7.98E+04	7.98E+04	7.98E+04	7.98E+04	7.98E+04	7.98E+04	7.98E+04	7.98E+04	7.98E+04	7.98E+04
MO 96	3.31E-02	7.29E+01	7.29E+01	7.29E+01	7.29E+01	7.29E+01	7.29E+01	7.29E+01	7.29E+01	7.29E+01	7.29E+01	7.29E+01
MO 97	3.54E+01	7.78E+04	7.78E+04	7.78E+04	7.78E+04	7.78E+04	7.78E+04	7.78E+04	7.78E+04	7.78E+04	7.78E+04	7.78E+04
MO 98	3.52E+01	7.74E+04	7.74E+04	7.74E+04	7.74E+04	7.74E+04	7.74E+04	7.74E+04	7.74E+04	7.74E+04	7.74E+04	7.74E+04
TC 99	3.73E+01	8.22E+04	8.22E+04	8.22E+04	8.22E+04	8.22E+04	8.22E+04	8.22E+04	8.22E+04	8.22E+04	8.21E+04	8.21E+04
RU 99	8.94E-05	3.62E-01	6.30E-01	8.99E-01	1.17E+00	1.70E+00	3.05E+00	4.39E+00	5.73E+00	8.42E+00	1.38E+01	2.72E+01
MO100	3.95E+01	8.69E+04	8.69E+04	8.69E+04	8.69E+04	8.69E+04	8.69E+04	8.69E+04	8.69E+04	8.69E+04	8.69E+04	8.69E+04
RU100	1.69E-01	3.72E+02	3.72E+02	3.72E+02	3.72E+02	3.72E+02	3.72E+02	3.72E+02	3.72E+02	3.72E+02	3.72E+02	3.72E+02
RU101	3.27E+01	7.19E+04	7.19E+04	7.19E+04	7.19E+04	7.19E+04	7.19E+04	7.19E+04	7.19E+04	7.19E+04	7.19E+04	7.19E+04
RU102	2.89E+01	6.35E+04	6.35E+04	6.35E+04	6.35E+04	6.35E+04	6.35E+04	6.35E+04	6.35E+04	6.35E+04	6.35E+04	6.35E+04
RH103	2.26E+01	4.98E+04	4.99E+04	4.99E+04	4.99E+04	4.99E+04	4.99E+04	4.99E+04	4.99E+04	4.99E+04	4.99E+04	4.99E+04
RU104	1.77E+01	3.89E+04	3.89E+04	3.89E+04	3.89E+04	3.89E+04	3.89E+04	3.89E+04	3.89E+04	3.89E+04	3.89E+04	3.89E+04
PD104	4.24E-01	9.32E+02	9.32E+02	9.32E+02	9.32E+02	9.32E+02	9.32E+02	9.32E+02	9.32E+02	9.32E+02	9.32E+02	9.32E+02
PD105	9.50E+00	2.09E+04	2.09E+04	2.09E+04	2.09E+04	2.09E+04	2.09E+04	2.09E+04	2.09E+04	2.09E+04	2.09E+04	2.09E+04
RU106	4.68E+00	6.95E+03	3.49E+03	1.75E+03	8.78E+02	2.21E+02	7.03E+00	2.24E-01	7.11E-03	7.19E-06	7.34E-12	7.76E-27
RH106	4.43E-06	6.58E-03	3.30E-03	1.66E-03	8.31E-04	2.09E-04	6.65E-06	2.11E-07	6.72E-09	6.80E-12	6.95E-18	7.34E-33
PD106	4.65E+00	1.36E+04	1.70E+04	1.88E+04	1.97E+04	2.03E+04	2.05E+04	2.05E+04	2.05E+04	2.05E+04	2.05E+04	2.05E+04

TABLE III-D-1 (Continued)

N REACTOR .947 ENRICHED PROPERTIES OF COLLECTED WASTE

POWER= 10.00MW, BURNUP= 1380.MWD, FLUX= 2.17E+13N/CM**2-SEC

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = 2200 TONS .947 ENR N REACTOR WASTE

	CHARGE	SEPARATION	1.0E+00YR	2.0E+00YR	3.0E+00YR	5.0E+00YR	1.0E+01YR	1.5E+01YR	2.0E+01YR	3.0E+01YR	5.0E+01YR	1.0E+02YR
PD107	4.80E+00	1.06E+04	1.06E+04	1.06E+04	1.06E+04	1.06E+04	1.06E+04	1.06E+04	1.06E+04	1.06E+04	1.06E+04	1.06E+04
AG107	3.36E-07	1.38E-03	2.43E-03	3.47E-03	4.52E-03	6.61E-03	1.18E-02	1.71E-02	2.23E-02	3.28E-02	5.37E-02	1.06E-01
PD108	2.90E+00	6.37E+03	6.37E+03	6.37E+03	6.37E+03	6.37E+03	6.37E+03	6.37E+03	6.37E+03	6.37E+03	6.37E+03	6.37E+03
CD108	1.92E-10	4.21E-07	4.21E-07	4.21E-07	4.21E-07	4.21E-07	4.21E-07	4.21E-07	4.21E-07	4.21E-07	4.21E-07	4.21E-07
AG109	1.51E+00	3.33E+03	3.33E+03	3.33E+03	3.33E+03	3.33E+03	3.33E+03	3.33E+03	3.33E+03	3.33E+03	3.33E+03	3.33E+03
CD109	8.01E-14	1.27E-10	7.29E-11	4.17E-11	2.38E-11	7.80E-12	4.77E-13	2.92E-14	1.79E-15	6.69E-18	9.38E-23	6.91E-35
PD110	6.37E-01	1.40E+03	1.40E+03	1.40E+03	1.40E+03	1.40E+03	1.40E+03	1.40E+03	1.40E+03	1.40E+03	1.40E+03	1.40E+03
AG110M	9.35E-04	1.18E+00	4.35E-01	1.60E-01	5.89E-02	7.96E-03	5.35E-05	3.60E-07	2.42E-09	1.09E-13	2.23E-22	0.
AG110	1.36E-10	1.72E-07	6.32E-08	2.32E-08	8.54E-09	1.16E-09	7.77E-12	5.22E-14	3.51E-16	1.59E-20	3.24E-29	0.
CD110	4.67E-02	1.04E+02	1.04E+02	1.05E+02	1.05E+02	1.05E+02	1.05E+02	1.05E+02	1.05E+02	1.05E+02	1.05E+02	1.05E+02
CD111	3.61E-01	7.95E+02	7.95E+02	7.95E+02	7.95E+02	7.95E+02	7.95E+02	7.95E+02	7.95E+02	7.95E+02	7.95E+02	7.95E+02
CD112	2.11E-01	4.65E+02	4.65E+02	4.65E+02	4.65E+02	4.65E+02	4.65E+02	4.65E+02	4.65E+02	4.65E+02	4.65E+02	4.65E+02
CD113M	4.65E-05	9.93E-02	9.45E-02	8.99E-02	8.56E-02	7.75E-02	6.05E-02	4.73E-02	3.69E-02	2.25E-02	8.36E-03	7.03E-04
CD113	5.64E-02	1.24E+02	1.24E+02	1.24E+02	1.24E+02	1.24E+02	1.24E+02	1.24E+02	1.24E+02	1.24E+02	1.24E+02	1.24E+02
IN113	1.56E-06	6.47E-03	1.13E-02	1.58E-02	2.02E-02	2.82E-02	4.52E-02	5.85E-02	6.86E-02	8.32E-02	9.73E-02	1.05E-01
CD114	3.51E-01	7.72E+02	7.72E+02	7.72E+02	7.72E+02	7.72E+02	7.72E+02	7.72E+02	7.72E+02	7.72E+02	7.72E+02	7.72E+02
SN114	2.70E-09	6.10E-06	6.13E-06	6.13E-06	6.13E-06	6.13E-06	6.13E-06	6.13E-06	6.13E-06	6.13E-06	6.13E-06	6.13E-06
IN115	1.13E-01	2.48E+02	2.48E+02	2.48E+02	2.48E+02	2.48E+02	2.48E+02	2.48E+02	2.48E+02	2.48E+02	2.48E+02	2.48E+02
SN115	6.01E-03	1.32E+01	1.32E+01	1.32E+01	1.32E+01	1.32E+01	1.32E+01	1.32E+01	1.32E+01	1.32E+01	1.32E+01	1.32E+01
CD116	1.19E-01	2.61E+02	2.61E+02	2.61E+02	2.61E+02	2.61E+02	2.61E+02	2.61E+02	2.61E+02	2.61E+02	2.61E+02	2.61E+02
SN116	9.55E-03	2.10E+01	2.10E+01	2.10E+01	2.10E+01	2.10E+01	2.10E+01	2.10E+01	2.10E+01	2.10E+01	2.10E+01	2.10E+01
SN117	1.23E-01	2.70E+02	2.70E+02	2.70E+02	2.70E+02	2.70E+02	2.70E+02	2.70E+02	2.70E+02	2.70E+02	2.70E+02	2.70E+02
SN118	1.24E-01	2.72E+02	2.72E+02	2.72E+02	2.72E+02	2.72E+02	2.72E+02	2.72E+02	2.72E+02	2.72E+02	2.72E+02	2.72E+02
SN119M	1.58E-04	1.99E-01	7.24E-02	2.63E-02	9.55E-03	1.26E-03	7.98E-06	5.05E-08	3.20E-10	1.28E-14	2.06E-23	0.
SN119	1.31E-01	2.89E+02	2.89E+02	2.89E+02	2.89E+02	2.89E+02	2.89E+02	2.89E+02	2.89E+02	2.89E+02	2.89E+02	2.89E+02
SN120	1.38E-01	3.04E+02	3.04E+02	3.04E+02	3.04E+02	3.04E+02	3.04E+02	3.04E+02	3.04E+02	3.04E+02	3.04E+02	3.04E+02
SN121M	3.13E-08	6.85E-05	6.76E-05	6.72E-05	6.68E-05	6.54E-05	6.25E-05	5.97E-05	5.71E-05	5.21E-05	4.34E-05	2.75E-05
SB121	1.55E-01	3.42E+02	3.42E+02	3.42E+02	3.42E+02	3.42E+02	3.42E+02	3.42E+02	3.42E+02	3.42E+02	3.42E+02	3.42E+02
SN122	1.65E-01	3.63E+02	3.63E+02	3.63E+02	3.63E+02	3.63E+02	3.63E+02	3.63E+02	3.63E+02	3.63E+02	3.63E+02	3.63E+02
TE122	5.42E-04	1.19E+00	1.19E+00	1.19E+00	1.19E+00	1.19E+00	1.19E+00	1.19E+00	1.19E+00	1.19E+00	1.19E+00	1.19E+00
SN123	3.69E-02	3.00E+01	3.95E+00	5.22E-01	6.89E-02	1.20E-03	4.81E-06	1.93E-12	7.73E-17	1.24E-25	3.21E-43	0.
SB123	1.48E-01	3.77E+02	4.03E+02	4.06E+02	4.07E+02	4.07E+02	4.07E+02	4.07E+02	4.07E+02	4.07E+02	4.07E+02	4.07E+02
TE123M	1.08E-08	8.32E-06	9.56E-07	1.10E-07	1.26E-08	1.67E-10	3.35E-15	6.72E-20	1.35E-24	5.42E-34	8.78E-53	0.
TE123	1.16E-07	2.71E-04	2.78E-04	2.79E-04	2.79E-04	2.79E-04	2.79E-04	2.79E-04	2.79E-04	2.79E-04	2.79E-04	2.79E-04
SN124	2.31E-01	5.09E+02	5.09E+02	5.09E+02	5.09E+02	5.09E+02	5.09E+02	5.09E+02	5.09E+02	5.09E+02	5.09E+02	5.09E+02
SB124	1.23E-05	5.19E-03	7.64E-05	1.12E-06	1.66E-08	3.59E-12	2.48E-21	1.71E-30	1.18E-39	5.66E-58	0.	0.
TE124	1.79E-04	4.16E-01	4.21E-01	4.21E-01	4.21E-01	4.21E-01	4.21E-01	4.21E-01	4.21E-01	4.21E-01	4.21E-01	4.21E-01
SB125	2.49E-01	4.70E+02	3.63E+02	2.81E+02	2.17E+02	1.30E+02	3.61E+01	9.99E+00	2.77E+00	2.13E-01	1.25E-03	3.35E-09
TE125M	5.67E-03	1.13E+01	8.85E+00	6.85E+00	5.30E+00	3.17E+00	8.79E-01	2.44E-01	6.75E-02	5.18E-03	3.06E-05	8.16E-11
TE125	4.29E-02	1.73E+02	2.82E+02	3.66E+02	4.31E+02	5.21E+02	6.17E+02	6.44E+02	6.51E+02	6.54E+02	6.54E+02	6.54E+02
SN126	5.07E-01	1.11E+03	1.11E+03	1.11E+03	1.11E+03	1.11E+03	1.11E+03	1.11E+03	1.11E+03	1.11E+03	1.11E+03	1.11E+03
SB126M	1.83E-10	4.03E-07	4.03E-07	4.03E-07	4.03E-07	4.03E-07	4.03E-07	4.03E-07	4.03E-07	4.03E-07	4.03E-07	4.02E-07
SB126	1.74E-07	3.78E-04	3.78E-04	3.78E-04	3.78E-04	3.78E-04	3.78E-04	3.78E-04	3.78E-04	3.78E-04	3.77E-04	3.77E-04
TE126	8.69E-04	1.92E+00	1.92E+00	1.93E+00	1.94E+00	1.96E+00	1.99E+00	2.03E+00	2.07E+00	2.15E+00	2.30E+00	2.69E+00
TE127M	5.59E-02	4.07E+01	3.99E+00	3.91E-01	3.84E-02	3.69E-04	3.35E-09	3.03E-14	2.75E-19	2.26E-29	1.53E-49	0.
TE127	1.99E+04	1.45E-01	1.42E-02	1.39E-03	1.36E-04	1.31E-06	1.19E-11	1.08E-16	9.77E-22	8.04E-32	5.44E-52	0.
I127	2.49E-01	6.32E+02	6.69E+02	6.72E+02	6.72E+02	6.73E+02	6.73E+02	6.73E+02	6.73E+02	6.73E+02	6.73E+02	6.73E+02
TE128	4.00E+00	8.79E+03	8.79E+03	8.79E+03	8.79E+03	8.79E+03	8.79E+03	8.79E+03	8.79E+03	8.79E+03	8.79E+03	8.79E+03
XE128	4.20E-03	9.24E+00	9.24E+00	9.24E+00	9.24E+00	9.24E+00	9.24E+00	9.24E+00	9.24E+00	9.24E+00	9.24E+00	9.24E+00
I129	1.71E+00	3.77E+03	3.77E+03	3.77E+03	3.77E+03	3.77E+03	3.77E+03	3.77E+03	3.77E+03	3.77E+03	3.77E+03	3.77E+03
XE129	3.05E-03	6.70E+00	6.70E+00	6.70E+00	6.70E+00	6.70E+00	6.70E+00	6.70E+00	6.70E+00	6.70E+00	6.71E+00	6.72E+00
TE130	1.65E+01	3.63E+04	3.63E+04	3.63E+04	3.63E+04	3.63E+04	3.63E+04	3.63E+04	3.63E+04	3.63E+04	3.63E+04	3.63E+04

TABLE III-D-1 (Continued)

N REACTOR .947 ENRICHED PROPERTIES OF COLLECTED WASTE

POWER= 10.00MW, BURNUP= 1380.MWD, FLUX= 2.17E+13N/CM**2-SEC

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = 2200 TONS .947 ENR N REACTOR WASTE

	CHARGE	SEPARATION	1.0E+00YR	2.0E+00YR	3.0E+00YR	5.0E+00YR	1.0E+01YR	1.5E+01YR	2.0E+01YR	3.0E+01YR	5.0E+01YR	1.0E+02YR
XE130	3.92E-02	8.62E+01	8.62E+01	8.62E+01	8.62E+01	8.62E+01	8.62E+01	8.62E+01	8.62E+01	8.62E+01	8.62E+01	8.62E+01
XE131	2.42E+01	5.32E+04	5.32E+04	5.32E+04	5.32E+04	5.32E+04	5.32E+04	5.32E+04	5.32E+04	5.32E+04	5.32E+04	5.32E+04
XE132	3.77E+01	8.28E+04	8.28E+04	8.28E+04	8.28E+04	8.28E+04	8.28E+04	8.28E+04	8.28E+04	8.28E+04	8.28E+04	8.28E+04
CS133	5.30E+01	1.16E+05	1.16E+05	1.16E+05	1.16E+05	1.16E+05	1.16E+05	1.16E+05	1.16E+05	1.16E+05	1.16E+05	1.16E+05
XE134	6.49E+01	1.43E+05	1.43E+05	1.43E+05	1.43E+05	1.43E+05	1.43E+05	1.43E+05	1.43E+05	1.43E+05	1.43E+05	1.43E+05
CS134	5.19E-01	9.34E+02	6.66E+02	4.75E+02	3.39E+02	1.72E+02	3.18E+01	5.86E+00	1.09E+00	3.68E-02	4.26E-05	1.95E-12
BA134	1.33E-01	5.01E+02	7.69E+02	9.60E+02	1.19E+03	1.26E+03	1.40E+03	1.43E+03	1.43E+03	1.43E+03	1.43E+03	1.43E+03
CS135	1.13E+01	2.48E+04	2.48E+04	2.48E+04	2.48E+04	2.48E+04	2.48E+04	2.48E+04	2.48E+04	2.48E+04	2.48E+04	2.48E+04
BA135	3.66E-06	1.16E-02	1.73E-02	2.30E-02	2.87E-02	4.02E-02	6.88E-02	9.75E-02	1.26E-01	1.83E-01	2.98E-01	5.84E-01
XE136	9.55E+01	2.10E+05	2.10E+05	2.10E+05	2.10E+05	2.10E+05	2.10E+05	2.10E+05	2.10E+05	2.10E+05	2.10E+05	2.10E+05
BA136	2.70E-01	4.85E+02	4.85E+02	4.85E+02	4.85E+02	4.85E+02	4.85E+02	4.85E+02	4.85E+02	4.85E+02	4.85E+02	4.85E+02
CS137	5.17E+01	1.12E+05	1.10E+05	1.07E+05	1.05E+05	1.00E+05	8.91E+04	7.94E+04	7.07E+04	5.61E+04	3.54E+04	1.11E+04
BA137M	7.82E-06	1.70E-02	1.56E-02	1.62E-02	1.58E-02	1.51E-02	1.35E-02	1.20E-02	1.07E-02	8.48E-03	5.34E-03	1.68E-03
BA137	8.89E-01	3.55E+03	6.12E+03	8.62E+03	1.11E+04	1.58E+04	2.67E+04	3.64E+04	4.51E+04	5.97E+04	8.04E+04	1.05E+05
BA138	4.97E+01	1.09E+05	1.09E+05	1.09E+05	1.09E+05	1.09E+05	1.09E+05	1.09E+05	1.09E+05	1.09E+05	1.09E+05	1.09E+05
LA139	5.49E+01	1.21E+05	1.21E+05	1.21E+05	1.21E+05	1.21E+05	1.21E+05	1.21E+05	1.21E+05	1.21E+05	1.21E+05	1.21E+05
CE140	5.61E+01	1.23E+05	1.23E+05	1.23E+05	1.23E+05	1.23E+05	1.23E+05	1.23E+05	1.23E+05	1.23E+05	1.23E+05	1.23E+05
PR141	5.30E+01	1.17E+05	1.17E+05	1.17E+05	1.17E+05	1.17E+05	1.17E+05	1.17E+05	1.17E+05	1.17E+05	1.17E+05	1.17E+05
CE142	5.09E+01	1.12E+05	1.12E+05	1.12E+05	1.12E+05	1.12E+05	1.12E+05	1.12E+05	1.12E+05	1.12E+05	1.12E+05	1.12E+05
ND142	5.23E-02	1.15E+02	1.15E+02	1.15E+02	1.15E+02	1.15E+02	1.15E+02	1.15E+02	1.15E+02	1.15E+02	1.15E+02	1.15E+02
ND143	4.64E+01	1.02E+05	1.02E+05	1.02E+05	1.02E+05	1.02E+05	1.02E+05	1.02E+05	1.02E+05	1.02E+05	1.02E+05	1.02E+05
CE144	2.43E+01	3.25E+04	1.33E+04	5.46E+03	2.24E+03	3.77E+02	4.37E+00	5.08E-02	5.89E-04	7.94E-08	1.44E-15	6.39E-35
PR144	1.03E-03	1.37E+00	5.63E-01	2.31E-01	9.48E-02	1.59E-02	1.85E-04	2.15E-06	2.49E-08	3.36E-12	6.09E-20	2.70E-39
ND144	2.42E+01	7.41E+04	9.33E+04	1.01E+05	1.04E+05	1.06E+05	1.07E+05	1.07E+05	1.07E+05	1.07E+05	1.07E+05	1.07E+05
ND145	3.39E+01	7.45E+04	7.45E+04	7.45E+04	7.45E+04	7.45E+04	7.45E+04	7.45E+04	7.45E+04	7.45E+04	7.45E+04	7.45E+04
ND146	2.75E+01	6.05E+04	6.05E+04	6.05E+04	6.05E+04	6.05E+04	6.05E+04	6.05E+04	6.05E+04	6.05E+04	6.05E+04	6.05E+04
PM147	1.68E+01	3.15E+04	2.42E+04	1.85E+04	1.42E+04	8.39E+03	2.23E+03	5.95E+02	1.59E+02	1.13E+01	5.68E-02	1.02E-07
SM147	3.37E+00	1.28E+04	2.01E+04	2.57E+04	3.00E+04	3.59E+04	4.20E+04	4.37E+04	4.41E+04	4.43E+04	4.43E+04	4.43E+04
ND148	1.58E+01	3.48E+04	3.48E+04	3.48E+04	3.48E+04	3.48E+04	3.48E+04	3.48E+04	3.48E+04	3.48E+04	3.48E+04	3.48E+04
SM148	1.00E+00	2.21E+03	2.22E+03	2.22E+03	2.22E+03	2.22E+03	2.22E+03	2.22E+03	2.22E+03	2.22E+03	2.22E+03	2.22E+03
SM149	1.48E+00	3.25E+03	3.25E+03	3.25E+03	3.25E+03	3.25E+03	3.25E+03	3.25E+03	3.25E+03	3.25E+03	3.25E+03	3.25E+03
ND150	6.78E+00	1.49E+04	1.49E+04	1.49E+04	1.49E+04	1.49E+04	1.49E+04	1.49E+04	1.49E+04	1.49E+04	1.49E+04	1.49E+04
SM150	1.08E+01	2.38E+04	2.38E+04	2.38E+04	2.38E+04	2.38E+04	2.38E+04	2.38E+04	2.38E+04	2.38E+04	2.38E+04	2.38E+04
SM151	4.11E+00	8.99E+03	8.92E+03	8.85E+03	8.78E+03	8.64E+03	8.30E+03	7.98E+03	7.67E+03	7.08E+03	6.04E+03	4.05E+03
EU151	2.14E-02	9.12E+01	1.63E+02	2.33E+02	3.04E+02	4.42E+02	7.80E+02	1.10E+03	1.42E+03	2.00E+03	3.05E+03	5.03E+03
SM152	4.15E+00	9.13E+03	9.13E+03	9.13E+03	9.13E+03	9.13E+03	9.13E+03	9.13E+03	9.13E+03	9.14E+03	9.14E+03	9.14E+03
EU152	1.35E-03	2.86E+00	2.70E+00	2.55E+00	2.40E+00	2.14E+00	1.61E+00	1.20E+00	9.01E-01	5.06E-01	1.59E-01	8.88E-03
GD152	8.15E-04	1.82E+00	1.87E+00	1.91E+00	1.95E+00	2.02E+00	2.17E+00	2.29E+00	2.37E+00	2.48E+00	2.58E+00	2.62E+00
EU153	2.33E+00	5.12E+03	5.12E+03	5.12E+03	5.12E+03	5.12E+03	5.12E+03	5.12E+03	5.12E+03	5.12E+03	5.12E+03	5.12E+03
GD153	5.24E-06	6.49E-03	7.28E-03	8.01E-04	2.81E-04	3.47E-05	1.86E-07	9.96E-10	5.34E-12	1.53E-16	1.26E-25	0.
SM154	1.15E+00	2.53E+03	2.53E+03	2.53E+03	2.53E+03	2.53E+03	2.53E+03	2.53E+03	2.53E+03	2.53E+03	2.53E+03	2.53E+03
EU154	1.22E-01	2.61E+02	2.50E+02	2.39E+02	2.29E+02	2.10E+02	1.69E+02	1.36E+02	1.10E+02	7.11E+01	2.99E+01	3.43E+00
GD154	3.61E-03	1.49E+01	2.60E+01	3.66E+01	4.67E+01	6.57E+01	1.07E+02	1.40E+02	1.66E+02	2.05E+02	2.46E+02	2.72E+02
EU155	1.75E-01	3.07E+02	2.09E+02	1.43E+02	9.73E+01	4.52E+01	6.67E+00	9.83E-01	1.45E-01	3.15E-03	1.49E-06	7.23E-15
GD155	4.32E-02	1.73E+02	2.70E+02	3.37E+02	3.82E+02	4.34E+02	4.73E+02	4.78E+02	4.79E+02	4.79E+02	4.79E+02	4.79E+02
GD156	7.90E-01	1.74E+03	1.74E+03	1.74E+03	1.74E+03	1.74E+03	1.74E+03	1.74E+03	1.74E+03	1.74E+03	1.74E+03	1.74E+03
GD157	6.06E-03	1.33E+01	1.33E+01	1.33E+01	1.33E+01	1.33E+01	1.33E+01	1.33E+01	1.33E+01	1.33E+01	1.33E+01	1.33E+01
GD158	2.80E-01	6.16E+02	6.16E+02	6.16E+02	6.16E+02	6.16E+02	6.16E+02	6.16E+02	6.16E+02	6.16E+02	6.16E+02	6.16E+02
TB159	4.35E-02	9.58E+01	9.58E+01	9.58E+01	9.58E+01	9.58E+01	9.58E+01	9.58E+01	9.58E+01	9.58E+01	9.58E+01	9.58E+01
GD160	1.81E-02	3.99E+01	3.99E+01	3.99E+01	3.99E+01	3.99E+01	3.99E+01	3.99E+01	3.99E+01	3.99E+01	3.99E+01	3.99E+01
TB160	6.75E-05	3.40E-02	1.02E-03	3.04E-05	9.07E-07	8.10E-10	1.93E-17	4.59E-25	1.09E-32	6.21E-48	0.	0.
DY160	5.97E-04	1.43E+00	1.46E+00	1.46E+00	1.46E+00	1.46E+00	1.46E+00	1.46E+00	1.46E+00	1.46E+00	1.46E+00	1.46E+00

9 1 1 1 3 9 1 1 4 0 5

TABLE III-D-1 (Continued)

N REACTOR .947 ENRICHED PROPERTIES OF COLLECTED WASTE

POWER= 10.00MW, BURNUP= 1390.MWD, FLUX= 2.17E+13N/CM**2-SEC

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = 2200 TONS .947 ENR N REACTOR WASTE

	CHARGE	SEPARATION	1.0E+00YR	2.0E+00YR	3.0E+00YR	5.0E+00YR	1.0E+01YR	1.5E+01YR	2.0E+01YR	3.0E+01YR	5.0E+01YR	1.0E+02YR
DY161	7.06E-03	1.55E+01	1.55E+01	1.55E+01	1.55E+01	1.55E+01	1.55E+01	1.55E+01	1.55E+01	1.55E+01	1.55E+01	1.55E+01
DY162	3.21E-03	7.06E+00	7.06E+00	7.06E+00	7.06E+00	7.06E+00	7.06E+00	7.06E+00	7.06E+00	7.06E+00	7.06E+00	7.06E+00
DY163	1.44E-03	3.17E+00	3.17E+00	3.17E+00	3.17E+00	3.17E+00	3.17E+00	3.17E+00	3.17E+00	3.17E+00	3.17E+00	3.17E+00
DY164	3.93E-04	8.65E-01	8.65E-01	8.65E-01	8.65E-01	8.65E-01	8.65E-01	8.65E-01	8.65E-01	8.65E-01	8.65E-01	8.65E-01
HO165	2.68E-04	5.89E-01	5.89E-01	5.89E-01	5.89E-01	5.89E-01	5.89E-01	5.89E-01	5.89E-01	5.89E-01	5.89E-01	5.89E-01
HO166M	6.73E-08	1.48E-04	1.48E-04	1.48E-04	1.48E-04	1.47E-04	1.47E-04	1.47E-04	1.46E-04	1.45E-04	1.44E-04	1.40E-04
ER166	9.69E-05	2.13E-01	2.13E-01	2.13E-01	2.13E-01	2.13E-01	2.13E-01	2.13E-01	2.13E-01	2.13E-01	2.13E-01	2.13E-01
ER167	1.13E-06	2.48E-03	2.48E-03	2.48E-03	2.48E-03	2.48E-03	2.48E-03	2.48E-03	2.48E-03	2.48E-03	2.48E-03	2.48E-03
SUBTOT	1.42E+03	3.13E+06	3.13E+06	3.13E+06	3.13E+06	3.13E+06	3.13E+06	3.13E+06	3.13E+06	3.13E+06	3.13E+06	3.13E+06
TOTAL	1.42E+03	3.13E+06	3.13E+06	3.13E+06	3.13E+06	3.13E+06	3.13E+06	3.13E+06	3.13E+06	3.13E+06	3.13E+06	3.13E+06

TABLE III-D-1 (Continued)

N REACTOR .947 ENRICHED PROPERTIES OF COLLECTED WASTE

POWER= 10.00MW, BURNUP= 1380.MWD, FLUX= 2.17E+13N/CM**2-SEC

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = 2200 TONS .947 ENR N REACTOR WASTE

	CHARGE	SEPARATION	3.0E+02YR	1.0E+03YR	3.0E+03YR	1.0E+04YR	3.0E+04YR	1.0E+05YR	3.0E+05YR	1.0E+06YR	1.0E+07YR	1.0E+08YR
H 3	2.71E-03	5.83E+00	2.66E-07	1.98E-24	0.	0.	0.	0.	0.	0.	0.	0.
GE 72	1.29E-04	2.84E-01	2.84E-01	2.84E-01	2.84E-01	2.84E-01	2.84E-01	2.84E-01	2.84E-01	2.84E-01	2.84E-01	2.84E-01
GE 73	5.18E-04	1.14E+00	1.14E+00	1.14E+00	1.14E+00	1.14E+00	1.14E+00	1.14E+00	1.14E+00	1.14E+00	1.14E+00	1.14E+00
GE 74	1.74E-03	3.83E+00	3.83E+00	3.83E+00	3.83E+00	3.83E+00	3.83E+00	3.83E+00	3.83E+00	3.83E+00	3.83E+00	3.83E+00
AS 75	3.47E-03	7.63E+00	7.63E+00	7.63E+00	7.63E+00	7.63E+00	7.63E+00	7.63E+00	7.63E+00	7.63E+00	7.63E+00	7.63E+00
GE 76	1.13E-02	2.48E+01	2.48E+01	2.48E+01	2.48E+01	2.48E+01	2.48E+01	2.48E+01	2.48E+01	2.48E+01	2.48E+01	2.48E+01
SE 76	4.84E-06	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.06E-02
SE 77	3.82E-02	8.41E+01	8.41E+01	8.41E+01	8.41E+01	8.41E+01	8.41E+01	8.41E+01	8.41E+01	8.41E+01	8.41E+01	8.41E+01
SE 78	9.65E-02	2.12E+02	2.12E+02	2.12E+02	2.12E+02	2.12E+02	2.12E+02	2.12E+02	2.12E+02	2.12E+02	2.12E+02	2.12E+02
SE 79	2.55E-01	5.61E+02	5.59E+02	5.55E+02	5.44E+02	5.04E+02	4.08E+02	1.93E+02	2.29E+01	1.31E-02	0.	0.
BR 79	2.31E-05	5.30E-02	1.95E+00	6.00E+00	1.77E+01	5.68E+01	1.54E+02	3.68E+02	5.38E+02	5.61E+02	5.61E+02	5.61E+02
SE 80	4.26E-01	9.38E+02	9.38E+02	9.38E+02	9.38E+02	9.38E+02	9.38E+02	9.38E+02	9.38E+02	9.38E+02	9.38E+02	9.38E+02
BR 81	6.96E-01	1.53E+03	1.53E+03	1.53E+03	1.53E+03	1.53E+03	1.53E+03	1.53E+03	1.53E+03	1.53E+03	1.53E+03	1.53E+03
SE 82	1.51E+00	3.32E+03	3.32E+03	3.32E+03	3.32E+03	3.32E+03	3.32E+03	3.32E+03	3.32E+03	3.32E+03	3.32E+03	3.32E+03
RB 85	4.50E+00	9.90E+03	9.90E+03	9.90E+03	9.90E+03	9.90E+03	9.90E+03	9.90E+03	9.90E+03	9.90E+03	9.90E+03	9.90E+03
SR 86	7.25E-04	1.60E+00	1.60E+00	1.60E+00	1.60E+00	1.60E+00	1.60E+00	1.60E+00	1.60E+00	1.60E+00	1.60E+00	1.60E+00
RB 87	1.18E+01	2.61E+04	2.61E+04	2.61E+04	2.61E+04	2.61E+04	2.61E+04	2.61E+04	2.61E+04	2.61E+04	2.60E+04	2.60E+04
SR 87	3.47E-08	7.55E-05	1.84E-04	4.37E-04	1.16E-03	3.69E-03	1.09E-02	3.62E-02	1.08E-01	3.61E-01	3.61E+00	3.61E+01
SR 88	1.71E+01	3.75E+04	3.75E+04	3.75E+04	3.75E+04	3.75E+04	3.75E+04	3.75E+04	3.75E+04	3.75E+04	3.75E+04	3.75E+04
Y 89	2.26E+01	5.08E+04	5.12E+04	5.12E+04	5.12E+04	5.12E+04	5.12E+04	5.12E+04	5.12E+04	5.12E+04	5.12E+04	5.12E+04
SR 90	2.75E+01	5.99E+04	3.67E+01	1.17E-06	4.43E-28	0.	0.	0.	0.	0.	0.	0.
Y 90	7.15E-03	1.56E+01	9.54E-03	3.03E-10	1.15E-31	0.	0.	0.	0.	0.	0.	0.
ZR 90	5.07E-01	1.67E+03	6.16E+04	6.16E+04	6.16E+04	6.16E+04	6.16E+04	6.16E+04	6.16E+04	6.16E+04	6.16E+04	6.16E+04
ZR 91	2.84E+01	6.45E+04	6.54E+04	6.54E+04	6.54E+04	6.54E+04	6.54E+04	6.54E+04	6.54E+04	6.54E+04	6.54E+04	6.54E+04
ZR 92	3.12E+01	6.86E+04	6.86E+04	6.86E+04	6.86E+04	6.86E+04	6.85E+04	6.86E+04	6.86E+04	6.86E+04	6.86E+04	6.86E+04
ZR 93	3.42E+01	7.52E+04	7.52E+04	7.52E+04	7.51E+04	7.49E+04	7.42E+04	7.18E+04	6.55E+04	4.74E+04	7.41E+02	6.49E-16
NB 93M	1.15E-05	3.75E-02	6.82E-01	6.82E-01	6.81E-01	6.79E-01	6.72E-01	6.51E-01	5.94E-01	4.30E-01	6.72E-03	5.88E-21
NB 93	2.23E-07	1.12E-03	9.78E+00	3.41E+01	1.04E+02	3.46E+02	1.03E+03	3.39E+03	9.73E+03	2.78E+04	7.45E+04	7.52E+04
ZR 94	3.50E+01	7.70E+04	7.70E+04	7.70E+04	7.70E+04	7.70E+04	7.70E+04	7.70E+04	7.70E+04	7.70E+04	7.70E+04	7.70E+04
MO 95	3.11E+01	7.49E+04	7.81E+04	7.81E+04	7.81E+04	7.81E+04	7.81E+04	7.81E+04	7.81E+04	7.81E+04	7.81E+04	7.81E+04
ZR 96	3.63E+01	7.98E+04	7.98E+04	7.98E+04	7.98E+04	7.98E+04	7.98E+04	7.98E+04	7.98E+04	7.98E+04	7.98E+04	7.98E+04
MO 96	3.31E-02	7.29E+01	7.29E+01	7.29E+01	7.29E+01	7.29E+01	7.29E+01	7.29E+01	7.29E+01	7.29E+01	7.29E+01	7.29E+01
MO 97	3.54E+01	7.78E+04	7.78E+04	7.78E+04	7.78E+04	7.78E+04	7.78E+04	7.78E+04	7.78E+04	7.78E+04	7.78E+04	7.78E+04
MO 98	3.52E+01	7.74E+04	7.74E+04	7.74E+04	7.74E+04	7.74E+04	7.74E+04	7.74E+04	7.74E+04	7.74E+04	7.74E+04	7.74E+04
TC 99	3.73E+01	8.22E+04	8.21E+04	8.19E+04	8.14E+04	7.95E+04	7.45E+04	5.93E+04	3.08E+04	3.13E+03	5.23E-10	0.
RU 99	8.94E-05	2.96E-01	8.08E+01	2.68E+02	8.02E+02	2.64E+03	7.67E+03	2.29E+04	5.13E+04	7.90E+04	8.22E+04	8.22E+04
MO100	3.95E+01	8.69E+04	8.69E+04	8.69E+04	8.69E+04	8.69E+04	8.69E+04	8.69E+04	8.69E+04	8.69E+04	8.69E+04	8.69E+04
RU100	1.69E-01	3.72E+02	3.72E+02	3.72E+02	3.72E+02	3.72E+02	3.72E+02	3.72E+02	3.72E+02	3.72E+02	3.72E+02	3.72E+02
RU101	3.27E+01	7.19E+04	7.19E+04	7.19E+04	7.19E+04	7.19E+04	7.19E+04	7.19E+04	7.19E+04	7.19E+04	7.19E+04	7.19E+04
RU102	2.89E+01	6.35E+04	6.35E+04	6.35E+04	6.35E+04	6.35E+04	6.35E+04	6.35E+04	6.35E+04	6.35E+04	6.35E+04	6.35E+04
RH103	2.24E+01	4.98E+04	4.99E+04	4.99E+04	4.99E+04	4.99E+04	4.99E+04	4.99E+04	4.99E+04	4.99E+04	4.99E+04	4.99E+04
RU104	1.77E+01	3.89E+04	3.89E+04	3.89E+04	3.89E+04	3.89E+04	3.89E+04	3.89E+04	3.89E+04	3.89E+04	3.89E+04	3.89E+04
PD104	4.24E-01	9.32E+02	9.32E+02	9.32E+02	9.32E+02	9.32E+02	9.32E+02	9.32E+02	9.32E+02	9.32E+02	9.32E+02	9.32E+02
PD105	9.50E+00	2.09E+04	2.09E+04	2.09E+04	2.09E+04	2.09E+04	2.09E+04	2.09E+04	2.09E+04	2.09E+04	2.09E+04	2.09E+04
PD106	4.65E+00	1.25E+04	2.05E+04	2.05E+04	2.05E+04	2.05E+04	2.05E+04	2.05E+04	2.05E+04	2.05E+04	2.05E+04	2.05E+04
PD107	4.80E+00	1.06E+04	1.06E+04	1.06E+04	1.06E+04	1.06E+04	1.05E+04	1.05E+04	1.03E+04	9.57E+03	3.93E+03	5.30E-01
AG107	3.34E-07	1.13E-03	3.15E-01	1.05E+00	3.14E+00	1.05E+01	3.13E+01	1.04E+02	3.09E+02	9.96E+02	6.64E+03	1.06E+04
PD108	2.90E+00	6.37E+03	6.37E+03	6.37E+03	6.37E+03	6.37E+03	6.37E+03	6.37E+03	6.37E+03	6.37E+03	6.37E+03	6.37E+03
CD108	1.92E-10	4.21E-07	4.21E-07	4.21E-07	4.21E-07	4.21E-07	4.21E-07	4.21E-07	4.21E-07	4.21E-07	4.21E-07	4.21E-07
AG109	1.51E+00	3.33E+03	3.33E+03	3.33E+03	3.33E+03	3.33E+03	3.33E+03	3.33E+03	3.33E+03	3.33E+03	3.33E+03	3.33E+03
PD110	6.37E-01	1.40E+03	1.40E+03	1.40E+03	1.40E+03	1.40E+03	1.40E+03	1.40E+03	1.40E+03	1.40E+03	1.40E+03	1.40E+03
CD110	4.67E-02	1.03E+02	1.05E+02	1.05E+02	1.05E+02	1.05E+02	1.05E+02	1.05E+02	1.05E+02	1.05E+02	1.05E+02	1.05E+02

TABLE III-D-1 (Continued)

N REACTOR .947 ENRICHED PROPERTIES OF COLLECTED WASTE

POWER= 10.00MW, BURNUP= 1300.MWD, FLUX= 2.17E+13N/CM**2-SEC

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = 2200 TONS .947 ENR N REACTOR WASTE

	CHARGE	SEPARATION	3.0E+02YR	1.0E+03YR	3.0E+03YR	1.0E+04YR	3.0E+04YR	1.0E+05YR	3.0E+05YR	1.0E+06YR	1.0E+07YR	1.0E+08YR
CD111	3.61E-01	7.95E+02	7.95E+02	7.95E+02	7.95E+02	7.95E+02	7.95E+02	7.95E+02	7.95E+02	7.95E+02	7.95E+02	7.95E+02
CD112	2.11E-01	4.65E+02	4.65E+02	4.65E+02	4.65E+02	4.65E+02	4.65E+02	4.65E+02	4.65E+02	4.65E+02	4.65E+02	4.65E+02
CD113M	4.65E-05	1.01E-01	3.57E-08	3.20E-23	0.	0.	0.	0.	0.	0.	0.	0.
CD113	5.64E-02	1.24E+02	1.24E+02	1.24E+02	1.24E+02	1.24E+02	1.24E+02	1.24E+02	1.24E+02	1.24E+02	1.24E+02	1.24E+02
IN113	1.56E-06	5.27E-03	1.06E-01	1.06E-01	1.06E-01	1.06E-01	1.05E-01	1.06E-01	1.06E-01	1.06E-01	1.06E-01	1.06E-01
CD114	3.51E-01	7.72E+02	7.72E+02	7.72E+02	7.72E+02	7.72E+02	7.72E+02	7.72E+02	7.72E+02	7.72E+02	7.72E+02	7.72E+02
SN114	2.70E-09	6.08E-06	6.13E-06	6.13E-06	6.13E-06	6.13E-06	6.13E-06	6.13E-06	6.13E-06	6.13E-06	6.13E-06	6.13E-06
IN115	1.13E-01	2.48E+02	2.48E+02	2.48E+02	2.48E+02	2.48E+02	2.49E+02	2.48E+02	2.48E+02	2.48E+02	2.48E+02	2.48E+02
SN115	6.01E-03	1.32E+01	1.32E+01	1.32E+01	1.32E+01	1.32E+01	1.32E+01	1.32E+01	1.32E+01	1.32E+01	1.32E+01	1.32E+01
CD116	1.19E-01	2.61E+02	2.61E+02	2.61E+02	2.61E+02	2.61E+02	2.61E+02	2.61E+02	2.61E+02	2.61E+02	2.61E+02	2.61E+02
SN116	9.55E-03	2.10E+01	2.10E+01	2.10E+01	2.10E+01	2.10E+01	2.10E+01	2.10E+01	2.10E+01	2.10E+01	2.10E+01	2.10E+01
SN117	1.23E-01	2.70E+02	2.70E+02	2.70E+02	2.70E+02	2.70E+02	2.70E+02	2.70E+02	2.70E+02	2.70E+02	2.70E+02	2.70E+02
SN118	1.24E-01	2.72E+02	2.72E+02	2.72E+02	2.72E+02	2.72E+02	2.72E+02	2.72E+02	2.72E+02	2.72E+02	2.72E+02	2.72E+02
SN119	1.31E-01	2.89E+02	2.89E+02	2.89E+02	2.89E+02	2.89E+02	2.89E+02	2.89E+02	2.89E+02	2.89E+02	2.89E+02	2.89E+02
SN120	1.38E-01	3.04E+02	3.04E+02	3.04E+02	3.04E+02	3.04E+02	3.04E+02	3.04E+02	3.04E+02	3.04E+02	3.04E+02	3.04E+02
SN121M	3.13E-08	6.86E-05	4.45E-06	7.52E-09	9.04E-17	0.	0.	0.	0.	0.	0.	0.
SB121	1.55E-01	3.42E+02	3.42E+02	3.42E+02	3.42E+02	3.42E+02	3.42E+02	3.42E+02	3.42E+02	3.42E+02	3.42E+02	3.42E+02
SN122	1.65E-01	3.63E+02	3.63E+02	3.63E+02	3.63E+02	3.63E+02	3.63E+02	3.63E+02	3.63E+02	3.63E+02	3.63E+02	3.63E+02
TE122	5.42E-04	1.19E+00	1.19E+00	1.19E+00	1.19E+00	1.19E+00	1.19E+00	1.19E+00	1.19E+00	1.19E+00	1.19E+00	1.19E+00
SB123	1.48E-01	3.65E+02	4.07E+02	4.07E+02	4.07E+02	4.07E+02	4.07E+02	4.07E+02	4.07E+02	4.07E+02	4.07E+02	4.07E+02
TE123	1.16E-07	2.67E-04	2.79E-04	2.79E-04	2.79E-04	2.79E-04	2.79E-04	2.79E-04	2.79E-04	2.79E-04	2.79E-04	2.79E-04
SN124	2.31E-01	5.09E+02	5.09E+02	5.09E+02	5.09E+02	5.09E+02	5.09E+02	5.09E+02	5.09E+02	5.09E+02	5.09E+02	5.09E+02
TE124	1.79E-04	4.12E-01	4.21E-01	4.21E-01	4.21E-01	4.21E-01	4.21E-01	4.21E-01	4.21E-01	4.21E-01	4.21E-01	4.21E-01
TE125	4.29E-02	1.44E+02	6.54E+02	6.54E+02	6.54E+02	6.54E+02	6.54E+02	6.54E+02	6.54E+02	6.54E+02	6.54E+02	6.54E+02
SN126	5.07E-01	1.11E+03	1.11E+03	1.11E+03	1.09E+03	1.04E+03	9.05E+02	5.57E+02	1.39E+02	1.09E+00	0.	0.
SB126M	1.83E-10	4.03E-07	4.02E-07	4.00E-07	3.94E-07	3.76E-07	3.27E-07	2.01E-07	5.04E-08	3.94E-10	0.	0.
SB126	1.74E-07	3.78E-04	3.77E-04	3.75E-04	3.70E-04	3.52E-04	3.07E-04	1.89E-04	4.72E-05	3.69E-07	0.	0.
TE126	8.69E-04	1.92E+00	4.23E+00	9.61E+00	2.48E+01	7.65E+01	2.11E+02	5.59E+02	9.77E+02	1.12E+03	1.12E+03	1.12E+03
I127	2.49E-01	6.14E+02	6.73E+02	6.73E+02	6.73E+02	6.73E+02	6.73E+02	6.73E+02	6.73E+02	6.73E+02	6.73E+02	6.73E+02
TE128	4.00E+00	8.79E+03	8.79E+03	8.79E+03	8.79E+03	8.79E+03	8.79E+03	8.79E+03	8.79E+03	8.79E+03	8.79E+03	8.79E+03
I129	1.71E+00	3.77E+03	3.77E+03	3.77E+03	3.77E+03	3.77E+03	3.77E+03	3.76E+03	3.73E+03	3.62E+03	2.51E+03	6.40E+01
XE129	1.90E-10	5.72E-05	4.62E-02	1.54E-01	4.61E-01	1.54E+00	4.61E+00	1.53E+01	4.58E+01	1.51E+02	1.26E+03	3.71E+03
TE130	1.65E+01	3.63E+04	3.63E+04	3.63E+04	3.63E+04	3.63E+04	3.63E+04	3.63E+04	3.63E+04	3.63E+04	3.63E+04	3.63E+04
XE131	1.20E-09	3.11E-05	3.24E-05	3.24E-05	3.24E-05	3.24E-05	3.24E-05	3.24E-05	3.24E-05	3.24E-05	3.24E-05	3.24E-05
CS133	5.30E+01	1.16E+05	1.16E+05	1.16E+05	1.16E+05	1.16E+05	1.16E+05	1.16E+05	1.16E+05	1.16E+05	1.16E+05	1.16E+05
BA134	1.33E-01	4.25E+02	1.43E+03	1.43E+03	1.43E+03	1.43E+03	1.43E+03	1.43E+03	1.43E+03	1.43E+03	1.43E+03	1.43E+03
CS135	1.13E+01	2.48E+04	2.48E+04	2.48E+04	2.48E+04	2.47E+04	2.46E+04	2.42E+04	2.31E+04	1.97E+04	2.46E+03	2.30E-06
BA135	3.66E-06	1.02E-02	1.73E+00	5.74E+00	1.72E+01	5.72E+01	1.71E+02	5.66E+02	1.66E+03	5.11E+03	2.23E+04	2.48E+04
BA136	2.20E-01	4.85E+02	4.85E+02	4.85E+02	4.85E+02	4.85E+02	4.85E+02	4.85E+02	4.85E+02	4.85E+02	4.85E+02	4.85E+02
CS137	5.17E+01	1.13E+05	1.10E+02	1.05E-05	9.04E-26	0.	0.	0.	0.	0.	0.	0.
BA137M	7.82E-06	1.71E-02	1.67E-05	1.58E-12	1.37E-32	0.	0.	0.	0.	0.	0.	0.
BA137	8.89E-01	2.92E+03	1.16E+05	1.16E+05	1.16E+05	1.16E+05	1.16E+05	1.16E+05	1.16E+05	1.16E+05	1.16E+05	1.16E+05
BA138	4.97E+01	1.09E+05	1.09E+05	1.09E+05	1.09E+05	1.09E+05	1.09E+05	1.09E+05	1.09E+05	1.09E+05	1.09E+05	1.09E+05
LA139	5.49E+01	1.21E+05	1.21E+05	1.21E+05	1.21E+05	1.21E+05	1.21E+05	1.21E+05	1.21E+05	1.21E+05	1.21E+05	1.21E+05
CE140	5.61E+01	1.23E+05	1.23E+05	1.23E+05	1.23E+05	1.23E+05	1.23E+05	1.23E+05	1.23E+05	1.23E+05	1.23E+05	1.23E+05
PR141	5.30E+01	1.17E+05	1.17E+05	1.17E+05	1.17E+05	1.17E+05	1.17E+05	1.17E+05	1.17E+05	1.17E+05	1.17E+05	1.17E+05
CE142	5.09E+01	1.12E+05	1.12E+05	1.12E+05	1.12E+05	1.12E+05	1.12E+05	1.12E+05	1.12E+05	1.12E+05	1.12E+05	1.12E+05
ND142	5.23E-02	1.15E+02	1.15E+02	1.15E+02	1.15E+02	1.15E+02	1.15E+02	1.15E+02	1.15E+02	1.15E+02	1.15E+02	1.15E+02
ND143	4.64E+01	1.02E+05	1.02E+05	1.02E+05	1.02E+05	1.02E+05	1.02E+05	1.02E+05	1.02E+05	1.02E+05	1.02E+05	1.02E+05
ND144	2.42E+01	6.75E+04	1.07E+05	1.07E+05	1.07E+05	1.07E+05	1.07E+05	1.07E+05	1.07E+05	1.07E+05	1.07E+05	1.07E+05
ND145	3.39E+01	7.45E+04	7.45E+04	7.45E+04	7.45E+04	7.45E+04	7.45E+04	7.45E+04	7.45E+04	7.45E+04	7.45E+04	7.45E+04
ND146	2.75E+01	6.05E+04	6.05E+04	6.05E+04	6.05E+04	6.05E+04	6.05E+04	6.05E+04	6.05E+04	6.05E+04	6.05E+04	6.05E+04

TABLE III-D-1 (Continued)

N REACTOR .947 ENRICHED PROPERTIES OF COLLECTED WASTE

POWER= 10.00MW, BURNUP= 1380.MWD, FLUX= 2.17E+13N/CM**2-SEC

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = 2200 TONS .947 ENR N REACTOR WASTE

	CHARGE	SEPARATION	3.0E+02YR	1.0E+03YR	3.0E+03YR	1.0E+04YR	3.0E+04YR	1.0E+05YR	3.0E+05YR	1.0E+06YR	1.0E+07YR	1.0E+08YR
SM147	3.37E+00	1.08E+04	4.43E+04	4.43E+04	4.43E+04	4.43E+04	4.43E+04	4.43E+04	4.43E+04	4.43E+04	4.43E+04	4.43E+04
ND148	1.58E+01	3.48E+04	3.48E+04	3.48E+04	3.48E+04	3.48E+04	3.48E+04	3.48E+04	3.48E+04	3.48E+04	3.48E+04	3.48E+04
SM148	1.00E+00	2.21E+03	2.22E+03	2.22E+03	2.22E+03	2.22E+03	2.22E+03	2.22E+03	2.22E+03	2.22E+03	2.22E+03	2.22E+03
SM149	1.48E+00	3.25E+03	3.25E+03	3.25E+03	3.25E+03	3.25E+03	3.25E+03	3.25E+03	3.25E+03	3.25E+03	3.25E+03	3.25E+03
ND150	6.78E+00	1.49E+04	1.49E+04	1.49E+04	1.49E+04	1.49E+04	1.49E+04	1.49E+04	1.49E+04	1.49E+04	1.49E+04	1.49E+04
SM150	1.08E+01	2.38E+04	2.38E+04	2.38E+04	2.38E+04	2.38E+04	2.38E+04	2.38E+04	2.38E+04	2.38E+04	2.38E+04	2.38E+04
SM151	4.11E+00	9.01E+03	8.26E+02	3.13E+00	3.77E-07	0.	0.	0.	0.	0.	0.	0.
EU151	2.14E-02	7.37E+01	8.26E+03	9.08E+03	9.08E+03	9.08E+03	9.08E+03	9.08E+03	9.08E+03	9.08E+03	9.08E+03	9.08E+03
SM152	4.15E+00	9.13E+03	9.14E+03	9.14E+03	9.14E+03	9.14E+03	9.14E+03	9.14E+03	9.14E+03	9.14E+03	9.14E+03	9.14E+03
EU152	1.35E-03	2.90E+00	8.67E-08	2.41E-25	0.	0.	0.	0.	0.	0.	0.	0.
GD152	8.15E-04	1.81E+00	2.62E+00	2.62E+00	2.62E+00	2.62E+00	2.62E+00	2.62E+00	2.62E+00	2.62E+00	2.62E+00	2.62E+00
EU153	2.33E+00	5.12E+03	5.12E+03	5.12E+03	5.12E+03	5.12E+03	5.12E+03	5.12E+03	5.12E+03	5.12E+03	5.12E+03	5.12E+03
SM154	1.15E+00	2.53E+03	2.53E+03	2.53E+03	2.53E+03	2.53E+03	2.53E+03	2.53E+03	2.53E+03	2.53E+03	2.53E+03	2.53E+03
EU154	1.22E-01	2.64E+02	6.00E-04	4.08E-17	0.	0.	0.	0.	0.	0.	0.	0.
GD154	3.61E-03	1.22E+01	2.76E+02	2.76E+02	2.76E+02	2.76E+02	2.76E+02	2.76E+02	2.76E+02	2.76E+02	2.76E+02	2.76E+02
GD155	4.32E-02	1.45E+02	4.79E+02	4.79E+02	4.79E+02	4.79E+02	4.79E+02	4.79E+02	4.79E+02	4.79E+02	4.79E+02	4.79E+02
GD156	7.90E-01	1.74E+03	1.74E+03	1.74E+03	1.74E+03	1.74E+03	1.74E+03	1.74E+03	1.74E+03	1.74E+03	1.74E+03	1.74E+03
GD157	6.06E-03	1.33E+01	1.33E+01	1.33E+01	1.33E+01	1.33E+01	1.33E+01	1.33E+01	1.33E+01	1.33E+01	1.33E+01	1.33E+01
GD158	2.80E-01	6.16E+02	6.16E+02	6.16E+02	6.16E+02	6.16E+02	6.16E+02	6.16E+02	6.16E+02	6.16E+02	6.16E+02	6.16E+02
TB159	4.35E-02	9.58E+01	9.58E+01	9.58E+01	9.58E+01	9.58E+01	9.58E+01	9.58E+01	9.58E+01	9.58E+01	9.58E+01	9.58E+01
GD160	1.81E-02	3.99E+01	3.99E+01	3.99E+01	3.99E+01	3.99E+01	3.99E+01	3.99E+01	3.99E+01	3.99E+01	3.99E+01	3.99E+01
DY160	5.97E-04	1.41E+00	1.46E+00	1.46E+00	1.46E+00	1.46E+00	1.46E+00	1.46E+00	1.46E+00	1.46E+00	1.46E+00	1.46E+00
DY161	7.06E-03	1.55E+01	1.55E+01	1.55E+01	1.55E+01	1.55E+01	1.55E+01	1.55E+01	1.55E+01	1.55E+01	1.55E+01	1.55E+01
DY162	3.21E-03	7.06E+00	7.06E+00	7.06E+00	7.06E+00	7.06E+00	7.06E+00	7.06E+00	7.06E+00	7.06E+00	7.06E+00	7.06E+00
DY163	1.44E-03	3.17E+00	3.17E+00	3.17E+00	3.17E+00	3.17E+00	3.17E+00	3.17E+00	3.17E+00	3.17E+00	3.17E+00	3.17E+00
DY164	3.93E-04	8.65E-01	8.65E-01	8.65E-01	8.65E-01	8.65E-01	8.65E-01	8.65E-01	8.65E-01	8.65E-01	8.65E-01	8.65E-01
HO165	2.68E-04	5.89E-01	5.89E-01	5.89E-01	5.89E-01	5.89E-01	5.89E-01	5.89E-01	5.89E-01	5.89E-01	5.89E-01	5.89E-01
HO166M	6.73E-08	1.48E-04	1.24E-04	8.30E-05	2.62E-05	4.59E-07	4.43E-12	1.23E-29	0.	0.	0.	0.
ER166	9.69E-05	2.13E-01	2.13E-01	2.13E-01	2.13E-01	2.13E-01	2.13E-01	2.13E-01	2.13E-01	2.13E-01	2.13E-01	2.13E-01
ER167	1.13E-06	2.48E-03	2.48E-03	2.48E-03	2.48E-03	2.48E-03	2.48E-03	2.48E-03	2.48E-03	2.48E-03	2.48E-03	2.48E-03
SUBTOT	1.15E+03	2.56E+06	2.64E+06	2.64E+06	2.64E+06	2.64E+06	2.64E+06	2.64E+06	2.64E+06	2.64E+06	2.64E+06	2.64E+06
TOTAL	1.20E+03	2.64E+06	2.64E+06	2.64E+06	2.64E+06	2.64E+06	2.64E+06	2.64E+06	2.64E+06	2.64E+06	2.64E+06	2.64E+06

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TABLE III-D-1 (Continued)

N REACTOR .947 ENRICHED PROPERTIES OF COLLECTED WASTE

POWER= 10.00MW, BURNUP= 1380.MWD, FLUX= 2.17E+13N/CM**2-SEC

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = 2200 TONS .947 ENR N REACTOR WASTE

	CHARGE	SEPARATION	1.0E+00YR	2.0E+00YR	3.0E+00YR	5.0E+00YR	1.0E+01YR	1.5E+01YR	2.0E+01YR	3.0E+01YR	5.0E+01YR	1.0E+02YR
HE 4	5.83E-04	1.33E+00	1.38E+00	1.41E+00	1.44E+00	1.51E+00	1.66E+00	1.81E+00	1.97E+00	2.27E+00	2.86E+00	4.26E+00
TL208	1.20E-14	2.13E-11	1.46E-11	1.02E-11	7.15E-12	3.55E-12	7.28E-13	2.67E-13	1.87E-13	1.58E-13	1.31E-13	8.06E-14
PB206	1.67E-16	5.53E-12	3.80E-11	1.33E-10	3.29E-10	1.17E-09	7.92E-09	2.42E-08	5.34E-08	1.62E-07	6.37E-07	3.76E-06
PB207	5.73E-13	6.66E-09	2.35E-08	5.08E-08	8.83E-08	1.92E-07	6.08E-07	1.22E-06	2.00E-06	3.98E-06	9.13E-06	2.54E-05
PB208	1.45E-09	7.75E-06	1.35E-05	1.75E-05	2.03E-05	2.37E-05	2.65E-05	2.72E-05	2.76E-05	2.81E-05	2.91E-05	3.07E-05
PB210	8.21E-14	8.57E-10	2.82E-09	5.98E-09	1.03E-08	2.23E-08	7.01E-08	1.40E-07	2.30E-07	4.56E-07	1.04E-06	2.87E-06
PB211	2.03E-15	1.11E-12	2.30E-12	3.34E-12	4.34E-12	6.25E-12	1.05E-11	1.42E-11	1.74E-11	2.24E-11	2.89E-11	3.56E-11
PB212	6.83E-12	1.24E-08	8.48E-09	5.93E-09	4.15E-09	2.06E-09	4.23E-10	1.55E-10	1.09E-10	9.20E-11	7.58E-11	4.68E-11
BI209	5.18E-14	2.99E-10	5.72E-10	8.45E-10	1.12E-09	1.68E-09	3.10E-09	4.61E-09	6.24E-09	9.97E-09	2.02E-08	7.40E-08
BI210	5.32E-17	5.45E-13	1.84E-12	3.91E-12	6.73E-12	1.46E-11	4.58E-11	9.18E-11	1.50E-10	2.98E-10	6.78E-10	1.87E-09
BI212	6.65E-13	1.18E-09	8.08E-10	5.65E-10	3.96E-10	1.96E-10	4.03E-11	1.48E-11	1.04E-11	8.77E-12	7.23E-12	4.46E-12
PO210	4.51E-16	7.44E-12	3.14E-11	7.62E-11	1.42E-10	3.35E-10	1.26E-09	2.53E-09	4.14E-09	8.20E-09	1.87E-08	5.16E-08
RN220	1.04E-16	1.84E-11	1.29E-11	9.03E-12	6.32E-12	3.14E-12	6.44E-13	2.37E-13	1.66E-13	1.40E-13	1.15E-13	7.13E-14
RN222	4.32E-15	2.23E-11	4.26E-11	6.31E-11	8.36E-11	1.25E-10	2.28E-10	3.31E-10	4.34E-10	6.43E-10	1.06E-09	2.14E-09
RA223	9.78E-14	5.33E-10	1.11E-09	1.60E-09	2.08E-09	3.00E-09	5.06E-09	6.83E-09	8.35E-09	1.08E-08	1.39E-08	1.71E-08
RA224	5.95E-11	1.07E-07	7.39E-08	5.16E-08	3.62E-08	1.79E-08	3.68E-09	1.35E-09	9.47E-10	8.01E-10	6.60E-10	4.08E-10
RA225	7.21E-15	1.71E-11	1.72E-11	1.73E-11	1.74E-11	1.75E-11	1.84E-11	1.97E-11	2.14E-11	2.59E-11	3.97E-11	1.03E-10
RA226	6.77E-10	3.45E-06	6.64E-06	9.63E-06	1.30E-05	1.94E-05	3.54E-05	5.15E-05	6.77E-05	1.00E-04	1.65E-04	3.33E-04
RA228	1.60E-15	5.56E-13	1.06E-12	1.52E-12	1.94E-12	2.65E-12	3.92E-12	4.69E-12	5.16E-12	5.65E-12	6.01E-12	6.42E-12
AC225	4.60E-15	1.15E-11	1.16E-11	1.17E-11	1.17E-11	1.19E-11	1.25E-11	1.33E-11	1.44E-11	1.75E-11	2.68E-11	6.95E-11
AC227	8.71E-11	4.18E-07	7.78E-07	1.13E-06	1.47E-06	2.11E-06	3.56E-06	4.81E-06	5.87E-06	7.57E-06	9.78E-06	1.20E-05
TH227	1.72E-13	8.90E-10	1.77E-09	2.57E-09	3.34E-09	4.81E-09	8.12E-09	1.09E-08	1.34E-08	1.73E-08	2.23E-08	2.74E-08
TH228	1.16E-09	2.05E-05	1.43E-05	1.00E-05	7.02E-06	3.48E-06	7.15E-07	2.63E-07	1.85E-07	1.56E-07	1.29E-07	7.95E-08
TH229	1.43E-09	3.14E-06	3.15E-06	3.17E-06	3.18E-06	3.22E-06	3.38E-06	3.61E-06	3.92E-06	4.74E-06	7.28E-06	1.89E-05
TH230	1.70E-04	3.75E-01	3.75E-01	3.76E-01	3.76E-01	3.77E-01	3.79E-01	3.81E-01	3.83E-01	3.87E-01	3.95E-01	4.15E-01
TH231	1.51E-08	1.78E-07	6.36E-08	6.36E-08	6.36E-08	6.36E-08	6.37E-08	6.37E-08	6.37E-08	6.37E-08	6.37E-08	6.37E-08
TH232	5.57E-06	1.23E-02	1.23E-02	1.23E-02	1.23E-02	1.23E-02	1.24E-02	1.25E-02	1.26E-02	1.28E-02	1.31E-02	1.39E-02
TH234	1.25E-05	2.17E-03	2.84E-05	2.84E-05	2.84E-05	2.84E-05	2.84E-05	2.84E-05	2.84E-05	2.84E-05	2.84E-05	2.84E-05
PA231	8.21E-06	1.81E-02	1.81E-02	1.81E-02	1.82E-02	1.82E-02	1.83E-02	1.83E-02	1.84E-02	1.86E-02	1.88E-02	1.96E-02
PA233	3.29E-07	1.32E-04	7.44E-05	7.44E-05	7.45E-05	7.46E-05	7.49E-05	7.52E-05	7.54E-05	7.60E-05	7.71E-05	7.98E-05
PA234M	4.23E-10	7.30E-08	9.59E-10	9.57E-10	9.57E-10	9.57E-10	9.57E-10	9.57E-10	9.57E-10	9.57E-10	9.57E-10	9.57E-10
PA234	1.48E-10	2.56E-08	3.32E-10	3.31E-10	3.31E-10	3.31E-10	3.31E-10	3.31E-10	3.31E-10	3.31E-10	3.31E-10	3.31E-10
U232	2.03E-09	4.86E-06	5.42E-06	5.84E-06	6.15E-06	6.55E-06	6.81E-06	6.65E-06	6.39E-06	5.82E-06	4.81E-06	2.97E-06
U233	4.53E-07	2.01E-03	2.83E-03	3.59E-03	4.35E-03	5.80E-03	9.25E-03	1.27E-02	1.62E-02	2.32E-02	3.73E-02	7.36E-02
U234	6.67E-02	1.47E+02	1.47E+02	1.47E+02	1.47E+02	1.47E+02	1.47E+02	1.47E+02	1.47E+02	1.48E+02	1.48E+02	1.49E+02
U235	7.16E+00	1.57E+04	1.57E+04	1.57E+04	1.57E+04	1.57E+04	1.57E+04	1.57E+04	1.57E+04	1.57E+04	1.57E+04	1.57E+04
U236	2.62E-01	5.77E+02	5.77E+02	5.77E+02	5.77E+02	5.77E+02	5.77E+02	5.77E+02	5.78E+02	5.78E+02	5.78E+02	5.79E+02
U237	4.90E-10	1.05E-06	9.98E-07	9.52E-07	9.05E-07	8.28E-07	6.55E-07	5.18E-07	4.10E-07	2.57E-07	1.01E-07	9.68E-09
U238	8.97E+02	1.97E+06	1.97E+06	1.97E+06	1.97E+06	1.97E+06	1.97E+06	1.97E+06	1.97E+06	1.97E+06	1.97E+06	1.97E+06
NP237	9.79E-01	2.16E+03	2.16E+03	2.16E+03	2.16E+03	2.16E+03	2.17E+03	2.18E+03	2.19E+03	2.21E+03	2.24E+03	2.32E+03
NP239	2.81E-09	1.88E-05	1.87E-05	1.87E-05	1.87E-05	1.87E-05	1.87E-05	1.87E-05	1.87E-05	1.87E-05	1.86E-05	1.86E-05
PU236	1.50E-09	2.84E-06	2.23E-06	1.75E-06	1.37E-06	8.43E-07	2.50E-07	7.41E-08	2.20E-08	1.93E-09	1.49E-11	7.83E-17
PU238	4.21E-04	2.59E+00	3.64E+00	3.84E+00	3.86E+00	3.82E+00	3.70E+00	3.58E+00	3.47E+00	3.25E+00	2.86E+00	2.08E+00
PU239	1.06E+00	2.33E+03	2.33E+03	2.33E+03	2.33E+03	2.33E+03	2.33E+03	2.33E+03	2.33E+03	2.33E+03	2.33E+03	2.32E+03
PU240	1.04E-01	2.29E+02	2.29E+02	2.29E+02	2.29E+02	2.29E+02	2.29E+02	2.29E+02	2.29E+02	2.29E+02	2.28E+02	2.27E+02
PU241	1.59E-02	3.40E+01	3.25E+01	3.10E+01	2.96E+01	2.69E+01	2.13E+01	1.69E+01	1.33E+01	8.35E+00	3.27E+00	3.15E-01
PU242	8.53E-04	1.88E+00	1.88E+00	1.88E+00	1.88E+00	1.88E+00	1.89E+00	1.89E+00	1.90E+00	1.91E+00	1.93E+00	1.97E+00
AM241	4.88E-01	1.07E+03	1.07E+03	1.07E+03	1.07E+03	1.07E+03	1.07E+03	1.07E+03	1.06E+03	1.05E+03	1.02E+03	9.45E+02
AM242M	6.11E-04	1.34E+00	1.33E+00	1.33E+00	1.32E+00	1.31E+00	1.28E+00	1.25E+00	1.22E+00	1.17E+00	1.07E+00	8.50E-01
AM242	7.34E-09	1.61E-05	1.60E-05	1.60E-05	1.59E-05	1.57E-05	1.54E-05	1.50E-05	1.47E-05	1.40E-05	1.28E-05	1.02E-05
AM243	1.03E-02	2.26E+01	2.26E+01	2.26E+01	2.26E+01	2.26E+01	2.26E+01	2.26E+01	2.26E+01	2.26E+01	2.25E+01	2.24E+01
CM242	1.40E-03	1.38E+00	2.94E-01	6.48E-02	1.62E-02	3.74E-03	3.09E-03	3.02E-03	2.95E-03	2.82E-03	2.57E-03	2.05E-03

TABLE III-D-1 (Continued)

N REACTOR .947 ENRICHED PROPERTIES OF COLLECTED WASTE

POWER= 10.00MW, BURNUP= 1380.MWD, FLUX= 2.17E+13N/CM**2-SEC

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = 2200 TONS .947 ENR N REACTOR WASTE

	CHARGE	SEPARATION	1.0E+00YR	2.0E+00YR	3.0E+00YR	5.0E+00YR	1.0E+01YR	1.5E+01YR	2.0E+01YR	3.0E+01YR	5.0E+01YR	1.0E+02YR
CM243	4.12E-06	8.95E-03	8.76E-03	8.57E-03	8.39E-03	8.03E-03	7.21E-03	6.47E-03	5.81E-03	4.67E-03	3.03E-03	1.03E-03
CM244	1.53E-04	3.29E-01	3.17E-01	3.05E-01	2.93E-01	2.72E-01	2.24E-01	1.85E-01	1.53E-01	1.04E-01	4.85E-02	7.15E-03
CM245	6.28E-07	1.38E-03	1.38E-03	1.38E-03	1.38E-03	1.38E-03	1.38E-03	1.38E-03	1.38E-03	1.36E-03	1.38E-03	1.37E-03
CM246	7.64E-09	1.68E-05	1.68E-05	1.68E-05	1.68E-05	1.68E-05	1.68E-05	1.68E-05	1.68E-05	1.67E-05	1.67E-05	1.66E-05
CM247	4.57E-12	1.01E-08	1.01E-08	1.01E-08	1.01E-08	1.01E-08	1.01E-08	1.01E-08	1.01E-08	1.01E-08	1.01E-08	1.01E-08
CM248	1.69E-14	3.72E-11	3.72E-11	3.72E-11	3.72E-11	3.72E-11	3.72E-11	3.72E-11	3.72E-11	3.71E-11	3.71E-11	3.71E-11
SUBTOT	9.07E+02	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06
TOTAL	9.07E+02	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06

TABLE III-D-1 (Continued)

N REACTOR .947 ENRICHED PROPERTIES OF COLLECTED WASTE

POWER= 10.00MW, BURNUP= 1380.MWD, FLUX= 2.17E+13N/CM**2-SEC

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = 2200 TONS .947 ENR N REACTOR WASTE

	CHARGE	SEPARATION	3.0E+02YR	1.0E+03YR	3.0E+03YR	1.0E+04YR	3.0E+04YR	1.0E+05YR	3.0E+05YR	1.0E+06YR	1.0E+07YR	1.0E+08YR
HE 4	5.83E-04	1.31E+00	8.92E+00	1.77E+01	2.41E+01	3.25E+01	4.76E+01	6.73E+01	9.36E+01	1.95E+02	8.65E+02	4.71E+03
TL207	2.64E-17	1.10E-13	5.64E-12	8.19E-12	1.53E-11	3.84E-11	9.06E-11	1.75E-10	2.03E-10	2.03E-10	2.01E-10	1.84E-10
PB206	1.67E-16	2.18E-12	5.46E-05	7.35E-04	8.41E-03	1.23E-01	1.27E+00	1.21E+01	6.70E+01	2.70E+02	2.63E+03	2.61E+04
PB207	5.73E-13	3.86E-09	1.05E-04	4.71E-04	2.26E-03	1.67E-02	1.17E-01	8.76E-01	3.88E+00	1.47E+01	1.54E+02	1.48E+03
PB208	1.45E-09	6.12E-06	3.32E-05	3.36E-05	3.36E-05	3.36E-05	3.40E-05	3.84E-05	7.82E-05	5.31E-04	4.59E-02	2.34E+00
PB209	5.59E-17	1.46E-13	6.74E-12	7.87E-11	7.46E-10	7.25E-09	4.06E-08	1.57E-07	3.47E-07	3.87E-07	1.98E-08	4.72E-21
PB210	8.21E-14	5.14E-10	1.28E-05	5.01E-05	1.95E-04	8.26E-04	2.70E-03	6.48E-03	9.36E-03	8.42E-03	8.10E-03	7.98E-03
PB211	2.03E-16	8.45E-13	4.35E-11	6.31E-11	1.18E-10	2.96E-10	6.98E-10	1.35E-09	1.56E-09	1.57E-09	1.55E-09	1.42E-09
PB212	6.83E-12	1.32E-08	6.85E-12	1.04E-14	5.04E-15	1.57E-14	5.01E-14	1.75E-13	5.32E-13	1.76E-12	1.56E-11	5.82E-11
PB214	2.03E-17	7.91E-14	3.16E-11	1.24E-10	4.82E-10	2.04E-09	6.68E-09	1.60E-08	2.31E-08	2.08E-08	2.00E-08	1.97E-08
BI209	5.18E-14	2.13E-10	1.29E-06	4.74E-05	1.36E-03	4.71E-02	8.95E-01	1.40E+01	1.14E+02	6.27E+02	2.75E+03	2.87E+03
BI210	5.32E-17	3.23E-13	9.36E-09	3.27E-08	1.27E-07	5.40E-07	1.76E-06	4.23E-06	6.11E-06	5.50E-06	5.29E-06	5.22E-06
BI211	1.21E-17	5.03E-14	2.59E-12	3.76E-12	7.03E-12	1.76E-11	4.16E-11	8.03E-11	9.31E-11	9.32E-11	9.24E-11	8.47E-11
BI213	1.42E-17	3.53E-14	1.63E-12	1.90E-11	1.80E-10	1.75E-09	9.82E-09	3.80E-08	8.39E-08	9.37E-08	4.78E-09	1.14E-21
BI214	1.49E-17	5.81E-14	2.33E-11	9.11E-11	3.54E-10	1.50E-09	4.91E-09	1.18E-08	1.70E-08	1.53E-08	1.47E-08	1.45E-08
PO210	4.51E-16	3.82E-12	2.30E-07	9.02E-07	3.51E-06	1.49E-05	4.86E-05	1.17E-04	1.68E-04	1.51E-04	1.46E-04	1.44E-04
PO218	2.36E-18	9.17E-15	3.67E-12	1.44E-11	5.59E-11	2.37E-10	7.74E-10	1.86E-09	2.68E-09	2.41E-09	2.32E-09	2.29E-09
RN222	4.32E-15	1.68E-11	6.74E-09	2.64E-08	1.03E-07	4.35E-07	1.42E-06	3.41E-06	4.93E-06	4.43E-06	4.26E-06	4.20E-06
RA223	9.78E-14	4.06E-10	2.09E-08	3.03E-08	5.67E-08	1.42E-07	3.35E-07	6.48E-07	7.51E-07	7.52E-07	7.46E-07	6.83E-07
RA224	5.95E-11	1.15E-07	5.96E-11	9.05E-14	4.39E-14	1.37E-13	4.36E-13	1.53E-12	4.63E-12	1.54E-11	1.36E-10	5.07E-10
RA225	7.21E-15	1.70E-11	7.91E-10	9.12E-09	8.64E-08	8.40E-07	4.70E-06	1.82E-05	4.02E-05	4.49E-05	2.29E-06	5.47E-19
RA226	6.77E-10	2.67E-06	1.05E-03	4.11E-03	1.60E-02	6.78E-02	2.21E-01	5.31E-01	7.68E-01	6.90E-01	6.64E-01	6.55E-01
RA228	1.00E-16	4.26E-13	8.04E-12	1.36E-11	3.00E-11	9.38E-11	2.98E-10	1.04E-09	3.17E-09	1.05E-08	9.27E-08	3.47E-07
AC225	4.60E-15	1.14E-11	5.28E-10	6.16E-09	5.84E-08	5.68E-07	3.18E-06	1.23E-05	2.71E-05	3.03E-05	1.55E-06	3.70E-19
AC227	8.71E-11	3.28E-07	1.47E-05	2.14E-05	3.99E-05	1.00E-04	2.36E-04	4.57E-04	5.29E-04	5.30E-04	5.25E-04	4.81E-04
TH227	1.72E-13	6.87E-10	3.35E-08	4.86E-08	9.09E-08	2.28E-07	5.37E-07	1.04E-06	1.20E-06	1.21E-06	1.20E-06	1.09E-06
TH228	1.16E-08	2.23E-05	1.16E-08	1.77E-11	8.50E-12	2.67E-11	8.50E-11	2.98E-10	9.04E-10	3.00E-09	2.64E-08	9.89E-08
TH229	1.43E-09	3.14E-06	1.43E-04	1.67E-03	1.58E-02	1.54E-01	8.62E-01	3.34E+00	7.37E+00	8.23E+00	4.20E-01	1.00E-13
TH230	1.70E-04	3.75E-01	4.97E-01	7.85E-01	1.60E+00	4.33E+00	1.12E+01	2.69E+01	3.90E+01	3.51E+01	3.38E+01	3.33E+01
TH231	1.51E-08	2.53E-07	6.37E-08	6.39E-08	6.44E-08	6.59E-08	6.90E-08	7.24E-08	7.30E-08	7.29E-08	7.23E-08	6.62E-08
TH232	5.57E-06	1.23E-02	1.72E-02	2.90E-02	6.43E-02	2.01E-01	6.39E-01	2.24E+00	6.79E+00	2.25E+01	1.99E+02	7.43E+02
TH234	1.25E-05	3.58E+03	2.84E-05	2.84E-05	2.84E-05	2.84E-05	2.84E-05	2.84E-05	2.84E-05	2.84E-05	2.83E-05	2.80E-05
PA231	8.21E-06	1.81E-02	2.25E-02	3.27E-02	6.11E-02	1.53E-01	3.62E-01	6.99E-01	8.10E-01	8.12E-01	8.04E-01	7.37E-01
PA233	3.29E-07	1.69E-04	8.86E-05	1.04E-04	1.11E-04	1.12E-04	1.11E-04	1.08E-04	1.02E-04	8.09E-05	4.39E-06	9.66E-19
PA234M	4.23E-10	1.21E-07	9.57E-10	9.57E-10	9.57E-10	9.57E-10	9.57E-10	9.57E-10	9.57E-10	9.57E-10	9.56E-10	9.43E-10
PA234	1.48E-10	4.22E-08	3.31E-10	3.31E-10	3.31E-10	3.31E-10	3.31E-10	3.31E-10	3.31E-10	3.31E-10	3.31E-10	3.26E-10
U232	2.03E-09	4.71E-06	4.34E-07	5.15E-10	2.25E-18	0.	0.	0.	0.	0.	0.	0.
U233	4.53E-07	1.81E-03	2.29E-01	8.60E-01	2.67E+00	9.90E+00	2.88E+01	8.25E+01	1.65E+02	1.85E+02	9.48E+00	2.26E-12
U234	6.67E-02	1.47E+02	1.51E+02	1.51E+02	1.51E+02	1.50E+02	1.48E+02	1.41E+02	1.26E+02	1.09E+02	1.06E+02	1.05E+02
U235	7.16E+00	1.57E+04	1.58E+04	1.58E+04	1.59E+04	1.63E+04	1.71E+04	1.79E+04	1.80E+04	1.80E+04	1.79E+04	1.64E+04
U236	2.62E-01	5.77E+02	5.84E+02	5.99E+02	6.37E+02	7.22E+02	7.92E+02	8.01E+02	7.96E+02	7.80E+02	6.01E+02	4.42E+01
U238	8.97E+02	1.97E+06	1.97E+06	1.97E+06	1.97E+06	1.97E+06	1.97E+06	1.97E+06	1.97E+06	1.97E+06	1.97E+06	1.94E+06
NP237	9.79E-01	2.16E+03	2.57E+03	3.03E+03	3.23E+03	3.24E+03	3.21E+03	3.14E+03	2.95E+03	2.35E+03	1.27E+02	2.80E-11
NP239	2.81E-09	1.88E-05	1.82E-05	1.71E-05	1.43E-05	7.57E-06	1.24E-06	2.18E-09	3.33E-17	3.66E-18	2.50E-18	5.58E-20
PU238	4.21E-04	2.15E+00	6.24E-01	1.70E-02	1.76E-06	2.43E-20	0.	0.	0.	0.	0.	0.
PU239	1.06E+00	2.33E+03	2.31E+03	2.27E+03	2.14E+03	1.76E+03	1.01E+03	1.38E+02	4.71E-01	1.11E-09	9.48E-12	2.12E-13
PU240	1.04E-01	2.29E+02	2.23E+02	2.07E+02	1.69E+02	8.23E+01	1.06E+01	8.10E-03	1.01E-11	2.30E-15	2.49E-15	1.17E-15
PU241	1.59E-02	3.44E+01	2.97E-05	2.24E-06	1.90E-06	1.05E-06	1.97E-07	5.57E-10	2.90E-17	0.	0.	0.
PU242	8.53E-04	1.88E+00	2.06E+00	2.11E+00	2.11E+00	2.08E+00	2.01E+00	1.76E+00	1.22E+00	3.40E-01	2.43E-08	0.
AM241	4.88E-01	1.07E+03	6.86E+02	2.24E+02	9.12E+00	1.55E-04	5.77E-06	1.63E-08	8.96E-16	0.	0.	0.
AM242M	6.11E-04	1.34E+00	3.42E-01	1.41E-02	1.54E-06	2.13E-20	0.	0.	0.	0.	0.	0.
AM242	7.34E-09	1.62E-05	4.10E-06	1.69E-07	1.85E-11	2.55E-25	0.	0.	0.	0.	0.	0.

TABLE III-D-1 (Continued)

N REACTOR .947 ENRICHED PROPERTIES OF COLLECTED WASTE

POWER= 10.00MW. BURNUP= 1380.MWD. FLUX= 2.17E+13N/CM**2-SEC

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = 2200 TONS .947 ENR N REACTOR WASTE

	CHARGE	SEPARATION	3.0E+02YR	1.0E+03YR	3.0E+03YR	1.0E+04YR	3.0E+04YR	1.0E+05YR	3.0E+05YR	1.0E+06YR	1.0E+07YR	1.0E+08YR
AM243	1.03E-02	2.26E+01	2.20E+01	2.07E+01	1.72E+01	9.15E+00	1.49E+00	2.63E-03	4.02E-11	4.42E-12	3.02E-12	6.74E-14
CM242	1.40E-03	1.83E+00	8.23E-04	3.38E-05	3.72E-09	5.13E-23	0.	0.	0.	0.	0.	0.
CM243	4.12E-06	9.00E-03	1.36E-05	3.54E-12	5.46E-31	0.	0.	0.	0.	0.	0.	0.
CM244	1.53E-04	3.32E-01	3.41E-06	7.83E-18	5.61E-23	1.86E-22	5.46E-22	1.70E-21	4.24E-21	8.15E-21	8.80E-21	4.14E-21
CM245	6.28E-07	1.38E-03	1.35E-03	1.27E-03	1.07E-03	5.97E-04	1.12E-04	3.16E+07	1.64E-14	0.	0.	0.
CM246	7.64E-09	1.68E-05	1.61E-05	1.45E-05	1.08E-05	3.86E-06	2.04E-07	6.87E-12	1.15E-24	0.	0.	0.
CM247	4.57E-12	1.01E-08	1.01E-08	1.01E-08	1.01E-08	1.00E-08	1.00E-08	1.00E-08	9.93E-09	9.64E-09	6.59E-09	1.47E-10
CM248	1.69E-14	3.72E-11	3.71E-11	3.71E-11	3.69E-11	3.64E-11	3.50E-11	3.05E-11	2.06E-11	5.19E-12	1.05E-19	0.
SUBTOT	9.07E+02	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06
TOTAL	9.07E+02	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06	2.00E+06

TABLE III-D-2 RADIOACTIVITY BY NUCLIDE, CURIES

N REACTOR .947 ENRICHED PROPERTIES OF COLLECTED WASTE

POWER= 10.00MW, BURNUP= 1380.MWD, FLUX= 2.17E+13N/CM**2-SEC

NUCLIDE RADIOACTIVITY, CURIES
BASIS = 2200 TONS .947 ENR N REACTOR WASTE

	CHARGE	SEPARATION	1.0E+00YR	2.0E+00YR	3.0E+00YR	5.0E+00YR	1.0E+01YR	1.5E+01YR	2.0E+01YR	3.0E+01YR	5.0E+01YR	1.0E+02YR
H 3	2.62E+01	5.58E+04	5.27E+04	4.98E+04	4.71E+04	4.21E+04	3.18E+04	2.40E+04	1.81E+04	1.03E+04	3.33E+03	1.99E+02
SE 79	1.78E-02	3.91E+01	3.91E+01	3.91E+01	3.91E+01	3.91E+01	3.91E+01	3.91E+01	3.91E+01	3.91E+01	3.91E+01	3.90E+01
RB 87	9.74E-07	2.14E-03	2.14E-03	2.14E-03	2.14E-03	2.14E-03	2.14E-03	2.14E-03	2.14E-03	2.14E-03	2.14E-03	2.14E-03
SR 89	2.02E+04	7.43E+06	5.71E+04	4.39E+02	3.36E+00	2.00E-04	5.39E-15	1.45E-25	3.91E-36	2.83E-57	0.	0.
SR 90	3.89E+03	8.43E+06	8.22E+06	8.02E+06	7.83E+06	7.45E+06	6.59E+06	5.82E+06	5.15E+06	4.02E+06	2.46E+06	7.16E+05
Y 90	3.89E+03	8.50E+06	8.22E+06	8.02E+06	7.83E+06	7.45E+06	6.59E+06	5.82E+06	5.15E+06	4.02E+06	2.46E+06	7.16E+05
Y 91	3.29E+04	1.36E+07	1.84E+05	2.49E+03	3.36E+01	6.12E-03	2.75E-12	1.24E-21	5.56E-31	1.12E-49	0.	0.
ZR 93	8.76E-02	1.93E+02	1.93E+02	1.93E+02	1.93E+02	1.93E+02	1.93E+02	1.93E+02	1.93E+02	1.93E+02	1.93E+02	1.93E+02
NB 93M	3.24E-03	1.28E+01	2.18E+01	3.03E+01	3.83E+01	5.33E+01	8.47E+01	1.09E+02	1.28E+02	1.54E+02	1.79E+02	1.92E+02
ZR 95	4.55E+04	2.08E+07	4.23E+05	8.62E+03	1.76E+02	7.28E-02	2.55E-10	8.92E-19	3.12E-27	3.83E-44	0.	0.
NB 95M	9.67E+02	4.58E+05	8.99E+03	1.83E+02	3.73E+00	1.54E-03	5.41E-12	1.89E-20	6.63E-29	8.13E-46	0.	0.
NB 95	8.85E+04	4.25E+07	9.39E+05	1.92E+04	3.90E+02	1.58E-01	5.53E-10	1.94E-18	6.78E-27	6.30E-44	0.	0.
TC 99	6.36E-01	1.40E+03	1.40E+03	1.40E+03	1.40E+03	1.40E+03	1.40E+03	1.40E+03	1.40E+03	1.40E+03	1.40E+03	1.40E+03
RU103	8.54E+03	2.39E+06	4.01E+03	6.72E+00	1.13E-02	3.16E-08	4.17E-22	5.50E-36	7.26E-50	0.	0.	0.
RH103M	8.55E+03	2.40E+06	4.02E+03	6.73E+00	1.13E-02	3.16E-08	4.17E-22	5.51E-36	7.27E-50	0.	0.	0.
RU106	1.57E+04	2.33E+07	1.17E+07	5.88E+06	2.95E+06	7.42E+05	2.36E+04	7.51E+02	2.39E+01	2.41E-02	2.47E-08	2.60E-23
RH106	1.57E+04	2.33E+07	1.17E+07	5.88E+06	2.95E+06	7.42E+05	2.36E+04	7.51E+02	2.39E+01	2.41E-02	2.47E-08	2.60E-23
PD107	2.29E-03	5.05E+00	5.05E+00	5.05E+00	5.05E+00	5.05E+00	5.05E+00	5.05E+00	5.05E+00	5.05E+00	5.05E+00	5.05E+00
AG109M	2.12E-10	3.37E-07	1.93E-07	1.10E-07	6.31E-08	2.06E-08	1.26E-09	7.73E-11	4.73E-12	1.77E-14	2.48E-19	1.83E-31
CD109	2.12E-10	3.37E-07	1.93E-07	1.10E-07	6.31E-08	2.06E-08	1.26E-09	7.73E-11	4.73E-12	1.77E-14	2.48E-19	1.83E-31
AG110M	4.39E+00	5.56E+03	2.04E+03	7.52E+02	2.76E+02	3.74E+01	2.51E-01	1.69E-03	1.14E-05	5.13E-10	1.05E-18	0.
AG110	5.70E-01	7.23E+02	2.66E+02	9.77E+01	3.59E+01	4.86E+00	3.27E-02	2.20E-04	1.48E-06	6.07E-11	1.36E-19	0.
CD113M	1.05E-02	2.25E+01	2.14E+01	2.03E+01	1.94E+01	1.75E+01	1.37E+01	1.07E+01	8.34E+00	5.09E+00	1.89E+00	1.59E-01
CD115M	3.65E+00	1.11E+02	3.09E+00	8.57E-03	2.48E-05	1.84E-10	3.03E-23	5.01E-36	8.26E-49	0.	0.	0.
SN119M	6.94E-01	8.75E+02	3.18E+02	1.15E+02	4.19E+01	5.54E+00	3.51E-02	2.22E-04	1.41E-06	5.63E-11	9.05E-20	0.
SN121M	1.22E-06	2.66E-03	2.64E-03	2.61E-03	2.59E-03	2.54E-03	2.43E-03	2.32E-03	2.22E-03	2.03E-03	1.69E-03	1.07E-03
SN123	3.14E+02	2.54E+05	3.36E+04	4.43E+03	5.85E+02	1.02E+01	4.09E-04	1.64E-08	6.57E-13	1.06E-21	2.73E-39	0.
TE123M	9.80E-05	7.55E-02	6.68E-03	9.99E-04	1.19E-04	1.51E-06	3.04E-11	6.10E-16	1.22E-20	4.92E-30	7.97E-49	0.
SB124	2.14E-01	9.12E+01	1.34E+00	1.98E-02	2.91E-04	6.30E-08	4.35E-17	3.01E-26	2.08E-35	9.93E-54	0.	0.
SB125	2.64E+02	4.98E+05	3.65E+05	2.98E+05	2.30E+05	1.38E+05	3.82E+04	1.06E+04	2.93E+03	2.25E+02	1.33E+00	3.55E-06
TE125M	1.02E+02	2.03E+05	1.59E+05	1.23E+05	9.55E+04	5.72E+04	1.58E+04	4.39E+03	1.22E+03	9.34E+01	5.51E-01	1.47E-06
SN126	1.44E-02	3.16E+01	3.16E+01	3.16E+01	3.16E+01	3.16E+01	3.16E+01	3.16E+01	3.16E+01	3.16E+01	3.16E+01	3.16E+01
SB126M	1.44E-02	3.16E+01	3.16E+01	3.16E+01	3.16E+01	3.16E+01	3.16E+01	3.16E+01	3.16E+01	3.16E+01	3.16E+01	3.16E+01
SB126	1.44E-02	3.13E+01	3.13E+01	3.13E+01	3.13E+01	3.13E+01	3.13E+01	3.13E+01	3.13E+01	3.13E+01	3.13E+01	3.13E+01
TE127M	5.28E+02	3.84E+05	3.76E+04	3.69E+03	3.62E+02	3.48E+00	3.16E-05	2.86E-10	2.60E-15	2.14E-25	1.44E-45	0.
TE127	5.22E+02	3.81E+05	3.72E+04	3.65E+03	3.58E+02	3.44E+00	3.12E-05	2.83E-10	2.57E-15	2.11E-25	1.43E-45	0.
I129	2.78E-04	6.15E-01	6.15E-01	6.15E-01	6.15E-01	6.15E-01	6.15E-01	6.15E-01	6.15E-01	6.15E-01	6.15E-01	6.15E-01
CS134	6.75E+02	1.22E+06	8.67E+05	6.18E+05	4.41E+05	2.24E+05	4.14E+04	7.63E+03	1.41E+03	4.79E+01	5.55E-02	2.53E-09
CS135	9.95E-03	2.19E+01	2.19E+01	2.19E+01	2.19E+01	2.19E+01	2.19E+01	2.19E+01	2.19E+01	2.19E+01	2.19E+01	2.19E+01
CS137	4.50E+03	9.76E+06	9.54E+06	9.32E+06	9.11E+06	8.70E+06	7.75E+06	6.91E+06	6.15E+06	4.88E+06	3.08E+06	9.69E+05
BA137M	4.21E+03	9.13E+06	8.92E+06	8.72E+06	8.52E+06	8.13E+06	7.25E+06	6.46E+06	5.75E+06	4.57E+06	2.88E+06	9.06E+05
CE141	6.63E+03	1.52E+06	6.16E+02	2.49E-01	1.01E-04	1.65E-11	1.80E-28	1.95E-45	2.12E-62	0.	0.	0.
CE144	7.75E+04	1.04E+08	4.25E+07	1.74E+07	7.16E+06	1.20E+06	1.40E+04	1.62E+02	1.88E+00	2.54E-04	4.60E-12	2.04E-31
PR144	7.75E+04	1.04E+08	4.25E+07	1.75E+07	7.16E+06	1.20E+06	1.40E+04	1.62E+02	1.88E+00	2.54E-04	4.60E-12	2.04E-31
PM147	1.56E+04	2.92E+07	2.24E+07	1.72E+07	1.32E+07	7.79E+06	2.07E+06	5.53E+05	1.47E+05	1.05E+04	5.27E+01	9.52E-05
PM148M	9.43E+01	2.80E+04	6.77E+01	1.63E-01	3.94E-04	2.30E-09	1.88E-22	1.54E-35	1.27E-48	0.	0.	0.
PM148	7.58E+00	2.25E+03	5.44E+00	1.31E-02	3.17E-05	1.85E-10	1.51E-23	1.24E-36	1.02E-49	0.	0.	0.
SM151	1.12E+02	2.45E+05	2.43E+05	2.41E+05	2.39E+05	2.35E+05	2.26E+05	2.17E+05	2.09E+05	1.93E+05	1.64E+05	1.10E+05
EU152	2.64E-01	5.61E+02	5.29E+02	5.00E+02	4.71E+02	4.20E+02	3.15E+02	2.36E+02	1.77E+02	9.92E+01	3.12E+01	1.74E+00
GD153	1.85E-02	2.29E+01	8.04E+00	2.83E+00	9.93E-01	1.23E-01	6.56E-04	3.52E-06	1.88E-08	5.40E-13	4.44E-22	0.
EU154	1.77E+01	3.79E+04	3.63E+04	3.47E+04	3.32E+04	3.05E+04	2.46E+04	1.98E+04	1.59E+04	1.03E+04	4.34E+03	4.98E+02
EU155	2.23E+02	3.91E+05	2.67E+05	1.82E+05	1.44E+05	5.77E+04	8.50E+03	1.25E+03	1.85E+02	4.02E+00	1.90E-03	9.21E-12

TABLE III-D-2 (Continued)

N REACTOR .947 ENRICHED PROPERTIES OF COLLECTED WASTE

POWER= 10.00MW, BURNUP= 1380.MWD, FLUX= 2.17E+13N/CM**2-SEC

NUCLIDE RADIOACTIVITY, CURIES
BASIS = 2200 TONS .947 ENR N REACTOR WASTE

	CHARGE	SEPARATION	1.0E+00YR	2.0E+00YR	3.0E+00YR	5.0E+00YR	1.0E+01YR	1.5E+01YR	2.0E+01YR	3.0E+01YR	5.0E+01YR	1.0E+02YR
TB160	7.64E-01	3.85E+02	1.15E+01	3.44E-01	1.03E-02	9.17E-06	2.18E-13	5.20E-21	1.24E-28	7.03E-44	0.	0.
HO166M	1.21E-07	2.66E-04	2.65E-04	2.65E-04	2.65E-04	2.65E-04	2.64E-04	2.63E-04	2.63E-04	2.61E-04	2.58E-04	2.51E-04
SUBTOT	4.33E+05	4.14E+08	1.70E+08	9.96E+07	6.74E+07	4.42E+07	3.07E+07	2.58E+07	2.26E+07	1.77E+07	1.10E+07	3.42E+06
TOTAL	4.34E+05	4.14E+08	1.70E+08	9.96E+07	6.74E+07	4.42E+07	3.07E+07	2.58E+07	2.26E+07	1.77E+07	1.10E+07	3.42E+06

N REACTOR .947 ENRICHED PROPERTIES OF COLLECTED WASTE

POWER= 10.00MW, BURNUP= 1380.MWD, FLUX= 2.17E+13N/CM**2-SEC

NUCLIDE RADIOACTIVITY, CURIES
BASIS = 2200 TONS .947 ENR N REACTOR WASTE

	CHARGE	SEPARATION	3.0E+02YR	1.0E+03YR	3.0E+03YR	1.0E+04YR	3.0E+04YR	1.0E+05YR	3.0E+05YR	1.0E+06YR	1.0E+07YR	1.0E+08YR
H 3	2.62E+01	5.65E+04	2.58E-03	1.92E-20	0.	0.	0.	0.	0.	0.	0.	0.
SE 79	1.78E-02	3.91E+01	3.90E+01	3.87E+01	3.74E+01	3.51E+01	2.84E+01	1.35E+01	1.60E+00	9.16E-04	0.	0.
RB 87	9.74E-07	2.14E-03	2.14E-03	2.14E-03	2.14E-03	2.14E-03	2.14E-03	2.14E-03	2.14E-03	2.14E-03	2.14E-03	2.14E-03
SR 90	3.89E+03	8.48E+06	5.19E+03	1.65E-04	6.20E-26	0.	0.	0.	0.	0.	0.	0.
Y 90	3.89E+03	8.48E+06	5.19E+03	1.65E-04	6.27E-26	0.	0.	0.	0.	0.	0.	0.
ZR 93	8.76E-02	1.93E+02	1.93E+02	1.93E+02	1.93E+02	1.92E+02	1.90E+02	1.84E+02	1.68E+02	1.21E+02	1.90E+00	1.66E-18
NB 93M	3.24E-03	1.06E+01	1.93E+02	1.93E+02	1.93E+02	1.92E+02	1.90E+02	1.84E+02	1.68E+02	1.21E+02	1.90E+00	1.66E-18
TC 99	6.36E-01	1.40E+03	1.40E+03	1.40E+03	1.39E+03	1.36E+03	1.27E+03	1.01E+03	5.25E+02	5.33E+01	8.91E-12	0.
PD107	2.29E-03	5.05E+00	5.05E+00	5.05E+00	5.05E+00	5.04E+00	5.03E+00	5.00E+00	4.90E+00	4.57E+00	1.88E+00	2.53E-04
CD113M	1.05E-02	2.27E+01	8.08E-06	7.23E-21	0.	0.	0.	0.	0.	0.	0.	0.
SN121M	1.22E-06	2.67E-03	1.73E-04	2.93E-07	3.52E-15	0.	0.	0.	0.	0.	0.	0.
SN126	1.44E-02	3.16E+01	3.16E+01	3.14E+01	3.10E+01	2.95E+01	2.57E+01	1.58E+01	3.96E+00	3.09E-02	0.	0.
SB126M	1.44E-02	3.16E+01	3.16E+01	3.14E+01	3.10E+01	2.95E+01	2.57E+01	1.58E+01	3.96E+00	3.09E-02	0.	0.
SB126	1.44E-02	3.14E+01	3.13E+01	3.11E+01	3.07E+01	2.92E+01	2.54E+01	1.57E+01	3.92E+00	3.06E-02	0.	0.
I129	2.78E-04	6.15E-01	6.15E-01	6.15E-01	6.15E-01	6.15E-01	6.14E-01	6.13E-01	6.08E-01	5.91E-01	4.09E-01	1.04E-02
CS135	9.95E-03	2.19E+01	2.19E+01	2.19E+01	2.19E+01	2.18E+01	2.17E+01	2.14E+01	2.04E+01	1.74E+01	2.17E+00	2.03E-09
CS137	4.50E+03	9.82E+06	9.60E+03	9.12E-04	7.86E-24	0.	0.	0.	0.	0.	0.	0.
BA137M	4.21E+03	9.18E+06	8.98E+03	8.53E-04	7.35E-24	0.	0.	0.	0.	0.	0.	0.
SM151	1.12E+02	2.45E+05	2.25E+04	8.52E+01	1.03E-05	0.	0.	0.	0.	0.	0.	0.
EU152	2.64E-01	5.69E+02	1.70E-05	4.73E-23	0.	0.	0.	0.	0.	0.	0.	0.
EU154	1.77E+01	3.83E+04	5.70E-02	5.92E-15	0.	0.	0.	0.	0.	0.	0.	0.
HO166M	1.21E-07	2.66E-04	2.23E-04	1.49E-04	4.70E-05	8.25E-07	7.95E-12	2.21E-29	0.	0.	0.	0.
SUBTOT	1.66E+04	3.63E+07	5.34E+04	2.03E+03	1.93E+03	1.89E+03	1.78E+03	1.47E+03	9.00E+02	3.19E+02	8.26E+00	1.28E-02
TOTAL	4.34E+05	5.21E+08	5.34E+04	2.03E+03	1.93E+03	1.89E+03	1.78E+03	1.47E+03	9.00E+02	3.19E+02	8.26E+00	1.28E-02

TABLE III-D-2 (Continued)

N REACTOR .947 ENRICHED PROPERTIES OF COLLECTED WASTE

POWER= 10.00MW. BURNUP= 1380.MWD. FLUX= 2.17E+13N/CM**2-SEC

NUCLIDE RADIOACTIVITY, CURIES
BASIS = 2200 TONS .947 ENR N REACTOR WASTE

	CHARGE	SEPARATION	1.0E+00YR	2.0E+00YR	3.0E+00YR	5.0E+00YR	1.0E+01YR	1.5E+01YR	2.0E+01YR	3.0E+01YR	5.0E+01YR	1.0E+02YR
TL207	5.01E-09	2.73E-05	5.67E-05	8.21E-05	1.07E-04	1.54E-04	2.59E-04	3.50E-04	4.28E-04	5.52E-04	7.12E-04	8.76E-04
TL208	3.51E-06	6.21E-03	4.26E-03	2.98E-03	2.04E-03	1.03E-03	2.12E-04	7.80E-05	5.46E-05	4.62E-05	3.81E-05	2.35E-05
TL209	5.88E-12	1.47E-08	1.46E-08	1.49E-08	1.50E-08	1.52E-08	1.59E-08	1.70E-08	1.84E-08	2.23E-08	3.42E-08	8.88E-08
PB209	2.54E-10	6.69E-07	6.74E-07	6.77E-07	6.81E-07	6.90E-07	7.24E-07	7.73E-07	8.38E-07	1.01E-06	1.56E-06	4.04E-06
PB210	6.66E-12	6.95E-08	2.29E-07	4.65E-07	8.36E-07	1.81E-06	5.69E-06	1.14E-05	1.87E-05	3.70E-05	8.42E-05	2.32E-04
PB211	5.02E-09	2.74E-05	5.68E-05	8.24E-05	1.07E-04	1.54E-04	2.60E-04	3.51E-04	4.29E-04	5.53E-04	7.14E-04	8.79E-04
PB212	9.53E-06	1.72E-02	1.18E-02	8.27E-03	5.79E-03	2.87E-03	5.90E-04	2.17E-04	1.52E-04	1.28E-04	1.06E-04	6.53E-05
PB214	6.66E-10	3.43E-06	6.57E-06	9.72E-06	1.29E-05	1.92E-05	3.51E-05	5.10E-05	6.69E-05	9.90E-05	1.64E-04	3.29E-04
BI210	6.61E-12	6.76E-08	2.29E-07	4.65E-07	8.36E-07	1.81E-06	5.69E-06	1.14E-05	1.87E-05	3.70E-05	8.42E-05	2.32E-04
BI211	5.02E-09	2.74E-05	5.68E-05	8.24E-05	1.07E-04	1.54E-04	2.60E-04	3.51E-04	4.29E-04	5.53E-04	7.14E-04	8.79E-04
BI212	9.74E-06	1.72E-02	1.18E-02	8.27E-03	5.79E-03	2.87E-03	5.90E-04	2.17E-04	1.52E-04	1.29E-04	1.06E-04	6.53E-05
BI213	2.67E-10	6.69E-07	6.74E-07	6.77E-07	6.81E-07	6.90E-07	7.24E-07	7.73E-07	8.38E-07	1.01E-06	1.56E-06	4.04E-06
BI214	6.66E-10	3.43E-06	6.57E-06	9.72E-06	1.29E-05	1.92E-05	3.51E-05	5.10E-05	6.69E-05	9.90E-05	1.64E-04	3.29E-04
PO210	2.03E-12	3.35E-08	1.42E-07	3.43E-07	6.39E-07	1.51E-06	5.69E-06	1.14E-05	1.87E-05	3.70E-05	8.42E-05	2.32E-04
PO211	1.51E-11	8.21E-08	1.70E-07	2.47E-07	3.21E-07	4.63E-07	7.81E-07	1.05E-06	1.29E-06	1.66E-06	2.14E-06	2.64E-06
PO212	6.24E-06	1.10E-02	7.57E-03	5.29E-03	3.71E-03	1.84E-03	3.78E-04	1.39E-04	9.71E-05	8.21E-05	6.77E-05	4.18E-05
PO213	2.61E-10	6.54E-07	6.60E-07	6.62E-07	6.66E-07	6.75E-07	7.08E-07	7.56E-07	8.19E-07	9.92E-07	1.52E-06	3.95E-06
PO214	6.66E-10	3.43E-06	6.57E-06	9.72E-06	1.29E-05	1.92E-05	3.51E-05	5.10E-05	6.69E-05	9.90E-05	1.64E-04	3.29E-04
PO215	5.02E-09	2.74E-05	5.68E-05	8.24E-05	1.07E-04	1.54E-04	2.60E-04	3.51E-04	4.29E-04	5.53E-04	7.14E-04	8.79E-04
PO216	9.54E-06	1.72E-02	1.18E-02	8.27E-03	5.79E-03	2.87E-03	5.90E-04	2.17E-04	1.52E-04	1.28E-04	1.06E-04	6.53E-05
PO218	6.66E-10	3.43E-06	6.57E-06	9.72E-06	1.29E-05	1.92E-05	3.51E-05	5.10E-05	6.69E-05	9.90E-05	1.64E-04	3.29E-04
AT217	2.67E-10	6.69E-07	6.74E-07	6.77E-07	6.81E-07	6.90E-07	7.24E-07	7.73E-07	8.38E-07	1.01E-06	1.56E-06	4.04E-06
RN219	5.02E-09	2.74E-05	5.68E-05	8.24E-05	1.07E-04	1.54E-04	2.60E-04	3.51E-04	4.29E-04	5.53E-04	7.14E-04	8.79E-04
RN220	9.54E-06	1.72E-02	1.18E-02	8.27E-03	5.79E-03	2.87E-03	5.90E-04	2.17E-04	1.52E-04	1.28E-04	1.06E-04	6.53E-05
RN222	6.66E-10	3.43E-06	6.57E-06	9.72E-06	1.29E-05	1.92E-05	3.51E-05	5.10E-05	6.69E-05	9.90E-05	1.64E-04	3.29E-04
FR221	2.67E-10	6.69E-07	6.74E-07	6.77E-07	6.81E-07	6.90E-07	7.24E-07	7.73E-07	8.38E-07	1.01E-06	1.56E-06	4.04E-06
FR223	8.89E-11	4.27E-07	7.95E-07	1.15E-06	1.50E-06	2.16E-06	3.64E-06	4.91E-06	6.00E-06	7.73E-06	9.98E-06	1.23E-05
RA223	5.02E-09	2.74E-05	5.68E-05	8.24E-05	1.07E-04	1.54E-04	2.60E-04	3.51E-04	4.29E-04	5.53E-04	7.14E-04	8.79E-04
RA224	9.53E-06	1.72E-02	1.18E-02	8.27E-03	5.79E-03	2.87E-03	5.90E-04	2.17E-04	1.52E-04	1.28E-04	1.06E-04	6.53E-05
RA225	2.83E-10	6.70E-07	6.74E-07	6.77E-07	6.81E-07	6.90E-07	7.24E-07	7.73E-07	8.38E-07	1.01E-06	1.56E-06	4.04E-06
RA226	6.70E-10	3.41E-06	6.57E-06	9.72E-06	1.29E-05	1.92E-05	3.51E-05	5.10E-05	6.69E-05	9.90E-05	1.64E-04	3.29E-04
RA228	2.35E-14	1.30E-10	2.49E-10	3.57E-10	4.54E-10	6.21E-10	9.17E-10	1.10E-09	1.21E-09	1.32E-09	1.41E-09	1.50E-09
AC225	2.67E-10	6.69E-07	6.74E-07	6.77E-07	6.81E-07	6.90E-07	7.24E-07	7.73E-07	8.38E-07	1.01E-06	1.56E-06	4.04E-06
AC227	6.35E-09	3.05E-05	5.68E-05	8.22E-05	1.07E-04	1.54E-04	2.60E-04	3.51E-04	4.28E-04	5.52E-04	7.13E-04	8.78E-04
AC228	2.34E-14	1.30E-10	2.49E-10	3.57E-10	4.54E-10	6.21E-10	9.17E-10	1.10E-09	1.21E-09	1.32E-09	1.41E-09	1.50E-09
TH227	5.44E-09	2.81E-05	5.60E-05	8.12E-05	1.06E-04	1.52E-04	2.57E-04	3.46E-04	4.23E-04	5.45E-04	7.04E-04	8.66E-04
TH228	9.49E-06	1.69E-02	1.18E-02	8.23E-03	5.76E-03	2.86E-03	5.87E-04	2.16E-04	1.52E-04	1.28E-04	1.06E-04	6.53E-05
TH229	3.05E-10	6.72E-07	6.74E-07	6.77E-07	6.81E-07	6.90E-07	7.24E-07	7.73E-07	8.38E-07	1.01E-06	1.56E-06	4.04E-06
TH230	3.31E-06	7.29E-03	7.30E-03	7.30E-03	7.31E-03	7.33E-03	7.37E-03	7.41E-03	7.44E-03	7.52E-03	7.68E-03	8.07E-03
TH231	8.02E-03	9.43E-02	3.37E-02	3.37E-02	3.37E-02	3.37E-02	3.37E-02	3.37E-02	3.37E-02	3.37E-02	3.38E-02	3.38E-02
TH232	6.09E-13	1.34E-09	1.34E-09	1.34E-09	1.35E-09	1.35E-09	1.36E-09	1.37E-09	1.38E-09	1.39E-09	1.43E-09	1.52E-09
TH234	2.90E-01	5.02E+01	6.59E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01
PA231	3.91E-07	8.63E-04	8.64E-04	8.64E-04	8.65E-04	8.66E-04	8.70E-04	8.73E-04	8.77E-04	8.84E-04	8.98E-04	9.33E-04
PA233	6.73E-03	2.69E+00	1.52E+00	1.52E+00	1.52E+00	1.53E+00	1.53E+00	1.54E+00	1.54E+00	1.56E+00	1.58E+00	1.63E+00
PA234M	2.90E-01	5.02E+01	6.59E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01
PA234	2.93E-04	5.08E-02	6.59E-04	6.58E-04	6.58E-04	6.58E-04	6.58E-04	6.58E-04	6.58E-04	6.58E-04	6.58E-04	6.58E-04
U232	4.34E-08	1.04E-04	1.16E-04	1.25E-04	1.32E-04	1.40E-04	1.46E-04	1.42E-04	1.37E-04	1.25E-04	1.03E-04	6.36E-05
U233	4.29E-09	1.90E-05	2.68E-05	3.40E-05	4.12E-05	5.50E-05	8.77E-05	1.21E-04	1.53E-04	2.20E-04	3.54E-04	6.97E-04
U234	4.17E-04	9.08E-01	9.08E-01	9.08E-01	9.08E-01	9.09E-01	9.09E-01	9.10E-01	9.11E-01	9.13E-01	9.16E-01	9.21E-01
U235	1.53E-05	3.37E-02	3.37E-02	3.37E-02	3.37E-02	3.37E-02	3.37E-02	3.37E-02	3.37E-02	3.37E-02	3.38E-02	3.38E-02
U236	1.66E-05	3.66E-02	3.66E-02	3.66E-02	3.66E-02	3.66E-02	3.66E-02	3.66E-02	3.66E-02	3.66E-02	3.67E-02	3.67E-02
U237	4.00E-05	8.54E-02	8.15E-02	7.78E-02	7.42E-02	6.76E-02	5.35E-02	4.23E-02	3.35E-02	2.10E-02	8.22E-03	7.91E-04

TABLE III-D-2 (Continued)

N REACTOR .947 ENRICHED PROPERTIES OF COLLECTED WASTE

POWER= 10.00MW, BURNUP= 1380.MWD, FLUX= 2.17E+13N/CM**2-SEC

NUCLIDE RADIOACTIVITY, CURIES
BASIS = 6200 TONS .947 ENR N REACTOR WASTE

	CHARGE	SEPARATION	1.0E+00YR	2.0E+00YR	3.0E+00YR	5.0E+00YR	1.0E+01YR	1.5E+01YR	2.0E+01YR	3.0E+01YR	5.0E+01YR	1.0E+02YR
U238	2.99E-04	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01
NP237	6.91E-04	1.52E+00	1.52E+00	1.52E+00	1.52E+00	1.53E+00	1.53E+00	1.54E+00	1.54E+00	1.56E+00	1.58E+00	1.63E+00
NP239	6.53E-04	4.37E+00	4.35E+00	4.35E+00	4.35E+00	4.35E+00	4.35E+00	4.35E+00	4.35E+00	4.34E+00	4.33E+00	4.32E+00
PU236	7.95E-07	1.51E-03	1.19E-03	9.30E-04	7.29E-04	4.48E-04	1.33E-04	3.94E-05	1.17E-05	1.03E-06	7.94E-09	4.16E-14
PU238	7.11E-03	4.38E+01	6.14E+01	6.48E+01	6.52E+01	6.46E+01	6.25E+01	6.05E+01	5.86E+01	5.49E+01	4.83E+01	3.51E+01
PU239	6.49E-02	1.43E+02	1.43E+02	1.43E+02	1.43E+02	1.43E+02	1.43E+02	1.43E+02	1.43E+02	1.43E+02	1.43E+02	1.42E+02
PU240	2.30E-02	5.05E+01	5.05E+01	5.05E+01	5.05E+01	5.05E+01	5.05E+01	5.05E+01	5.05E+01	5.04E+01	5.03E+01	5.01E+01
PU241	1.60E+00	3.41E+03	3.26E+03	3.11E+03	2.90E+03	2.70E+03	2.14E+03	1.69E+03	1.34E+03	8.37E+02	3.28E+02	3.16E+01
PU242	3.33E-06	7.32E-03	7.32E-03	7.33E-03	7.33E-03	7.34E-03	7.36E-03	7.38E-03	7.40E-03	7.44E-03	7.51E-03	7.66E-03
AM241	1.67E+00	3.68E+03	3.68E+03	3.68E+03	3.68E+03	3.67E+03	3.66E+03	3.65E+03	3.63E+03	3.59E+03	3.50E+03	3.24E+03
AM242M	5.94E-03	1.30E+01	1.30E+01	1.29E+01	1.28E+01	1.27E+01	1.25E+01	1.22E+01	1.19E+01	1.14E+01	1.04E+01	8.26E+00
AM242	5.94E-03	1.31E+01	1.30E+01	1.29E+01	1.28E+01	1.27E+01	1.25E+01	1.22E+01	1.19E+01	1.14E+01	1.04E+01	8.26E+00
AM243	1.98E-03	4.35E+00	4.35E+00	4.35E+00	4.35E+00	4.35E+00	4.35E+00	4.35E+00	4.35E+00	4.34E+00	4.33E+00	4.32E+00
CM242	4.54E+00	4.56E+03	9.74E+02	2.15E+02	5.37E+01	1.24E+01	1.02E+01	9.99E+00	9.76E+00	9.32E+00	8.51E+00	6.78E+00
CM243	1.90E-04	4.12E-01	4.03E-01	3.94E-01	3.86E-01	3.69E-01	3.32E-01	2.98E-01	2.67E-01	2.15E-01	1.39E-01	4.72E-02
CM244	1.24E-02	2.67E+01	2.57E+01	2.47E+01	2.38E+01	2.20E+01	1.82E+01	1.50E+01	1.24E+01	8.45E+00	3.93E+00	5.79E-01
CM245	1.11E-07	2.44E-04	2.44E-04	2.44E-04	2.44E-04	2.44E-04	2.44E-04	2.44E-04	2.44E-04	2.43E-04	2.43E-04	2.42E-04
CM246	2.36E-09	5.19E-06	5.19E-06	5.19E-06	5.19E-06	5.18E-06	5.18E-06	5.18E-06	5.17E-06	5.16E-06	5.15E-06	5.11E-06
SUBTOT	8.63E+00	1.21E+04	8.23E+03	7.32E+03	7.02E+03	6.71E+03	6.13E+03	5.66E+03	5.28E+03	4.73E+03	4.11E+03	3.54E+03
TOTAL	8.63E+00	1.21E+04	8.23E+03	7.32E+03	7.02E+03	6.71E+03	6.13E+03	5.66E+03	5.28E+03	4.73E+03	4.11E+03	3.54E+03

TABLE III-D-2 (Continued)

N REACTOR .947 ENRICHED PROPERTIES OF COLLECTED WASTE

POWER= 10.00MW, BURNUP= 1380.MWD, FLUX= 2.17E+13N/CM**2-SEC

NUCLIDE RADIOACTIVITY, CURIES
BASIS = 2200 TONS .947 ENR N REACTOR WASTE

	CHARGE	SEPARATION	3.0E+02YR	1.0E+03YR	3.0E+03YR	1.0E+04YR	3.0E+04YR	1.0E+05YR	3.0E+05YR	1.0E+06YR	1.0E+07YR	1.0E+08YR
TL207	5.01E-09	2.08E-05	1.07E-03	1.55E-03	2.91E-03	7.28E-03	1.72E-02	3.32E-02	3.85E-02	3.85E-02	3.82E-02	3.50E-02
TL208	3.51E-06	6.65E-03	3.44E-06	5.22E-09	2.53E-09	7.90E-09	2.51E-08	8.81E-08	2.67E-07	8.86E-07	7.82E-06	2.93E-05
TL209	5.88E-12	1.46E-08	6.74E-07	7.87E-06	7.46E-05	7.25E-04	4.06E-03	1.57E-02	3.47E-02	3.87E-02	1.98E-03	4.72E-16
PB209	2.54E-10	6.64E-07	3.07E-05	3.58E-04	3.39E-03	3.30E-02	1.84E-01	7.14E-01	1.58E+00	1.76E+00	8.98E-02	2.15E-14
PB210	6.66E-12	4.17E-08	1.04E-03	4.06E-03	1.58E-02	6.70E-02	2.19E-01	5.26E-01	7.59E-01	6.83E-01	6.57E-01	6.48E-01
PB211	5.02E-09	2.09E-05	1.07E-03	1.56E-03	2.91E-03	7.30E-03	1.72E-02	3.33E-02	3.86E-02	3.87E-02	3.83E-02	3.51E-02
PB212	9.53E-06	1.85E-02	9.55E-06	1.45E-08	7.03E-09	2.20E-08	6.98E-08	2.45E-07	7.42E-07	2.46E-06	2.17E-05	8.13E-05
PB214	6.66E-10	2.59E-06	1.04E-03	4.06E-03	1.58E-02	6.70E-02	2.19E-01	5.26E-01	7.59E-01	6.83E-01	6.57E-01	6.48E-01
BI210	6.61E-12	4.01E-08	1.04E-03	4.06E-03	1.58E-02	6.70E-02	2.19E-01	5.26E-01	7.59E-01	6.83E-01	6.57E-01	6.48E-01
BI211	5.02E-09	2.09E-05	1.07E-03	1.56E-03	2.91E-03	7.30E-03	1.72E-02	3.33E-02	3.86E-02	3.87E-02	3.83E-02	3.51E-02
BI212	9.74E-06	1.85E-02	9.55E-06	1.45E-08	7.03E-09	2.20E-08	6.98E-08	2.45E-07	7.42E-07	2.46E-06	2.17E-05	8.13E-05
BI213	2.67E-10	6.64E-07	3.07E-05	3.58E-04	3.39E-03	3.30E-02	1.84E-01	7.14E-01	1.58E+00	1.76E+00	8.98E-02	2.15E-14
BI214	6.66E-10	2.59E-06	1.04E-03	4.05E-03	1.58E-02	6.70E-02	2.19E-01	5.26E-01	7.59E-01	6.83E-01	6.57E-01	6.48E-01
PO210	2.03E-12	1.72E-08	1.04E-03	4.05E-03	1.58E-02	6.70E-02	2.19E-01	5.26E-01	7.59E-01	6.83E-01	6.57E-01	6.48E-01
PO211	1.51E-11	6.26E-08	3.22E-06	4.69E-06	8.74E-06	2.19E-05	5.17E-05	9.99E-05	1.16E-04	1.16E-04	1.15E-04	1.05E-04
PO212	6.24E-06	1.18E-02	6.11E-06	9.28E-09	4.50E-09	1.41E-08	4.47E-08	1.57E-07	4.75E-07	1.58E-06	1.39E-05	5.20E-05
PO213	2.61E-10	6.49E-07	3.00E-05	3.50E-04	3.31E-03	3.22E-02	1.80E-01	6.98E-01	1.54E+00	1.72E+00	8.78E-02	2.10E-14
PO214	6.66E-10	2.59E-06	1.04E-03	4.06E-03	1.58E-02	6.70E-02	2.19E-01	5.26E-01	7.59E-01	6.83E-01	6.57E-01	6.48E-01
PO215	5.02E-09	2.09E-05	1.07E-03	1.56E-03	2.91E-03	7.30E-03	1.72E-02	3.33E-02	3.86E-02	3.87E-02	3.83E-02	3.51E-02
PO216	9.54E-06	1.84E-02	9.55E-06	1.45E-08	7.03E-09	2.20E-08	6.98E-08	2.45E-07	7.42E-07	2.46E-06	2.17E-05	8.13E-05
PO218	6.66E-10	2.59E-06	1.04E-03	4.06E-03	1.58E-02	6.70E-02	2.19E-01	5.26E-01	7.59E-01	6.83E-01	6.57E-01	6.48E-01
AT217	2.67E-10	6.63E-07	3.07E-05	3.58E-04	3.39E-03	3.30E-02	1.84E-01	7.14E-01	1.58E+00	1.76E+00	8.98E-02	2.15E-14
RN219	5.02E-09	2.09E-05	1.07E-03	1.56E-03	2.91E-03	7.30E-03	1.72E-02	3.33E-02	3.86E-02	3.87E-02	3.83E-02	3.51E-02
RN220	9.54E-06	1.84E-02	9.55E-06	1.45E-08	7.03E-09	2.20E-08	6.98E-08	2.45E-07	7.42E-07	2.46E-06	2.17E-05	8.13E-05
RN222	6.66E-10	2.59E-06	1.04E-03	4.06E-03	1.58E-02	6.70E-02	2.19E-01	5.26E-01	7.59E-01	6.83E-01	6.57E-01	6.48E-01
FR221	2.67E-10	6.63E-07	3.07E-05	3.58E-04	3.39E-03	3.30E-02	1.84E-01	7.14E-01	1.58E+00	1.76E+00	8.98E-02	2.15E-14
FR223	8.89E-11	3.35E-07	1.50E-05	2.18E-05	4.08E-05	1.02E-04	2.41E-04	4.66E-04	5.40E-04	5.41E-04	5.37E-04	4.91E-04
RA223	5.02E-09	2.09E-05	1.07E-03	1.56E-03	2.91E-03	7.30E-03	1.72E-02	3.33E-02	3.86E-02	3.87E-02	3.83E-02	3.51E-02
RA224	9.53E-06	1.84E-02	9.55E-06	1.45E-08	7.03E-09	2.20E-08	6.98E-08	2.45E-07	7.42E-07	2.46E-06	2.17E-05	8.13E-05
RA225	2.83E-10	6.68E-07	3.07E-05	3.58E-04	3.39E-03	3.30E-02	1.84E-01	7.14E-01	1.58E+00	1.76E+00	8.98E-02	2.15E-14
RA226	6.70E-10	2.64E-06	1.04E-03	4.06E-03	1.58E-02	6.70E-02	2.19E-01	5.26E-01	7.59E-01	6.83E-01	6.57E-01	6.48E-01
RA228	2.35E-14	9.97E-11	1.88E-09	3.17E-09	7.03E-09	2.20E-08	6.98E-08	2.45E-07	7.42E-07	2.46E-06	2.17E-05	8.13E-05
AC225	2.67E-10	6.63E-07	3.07E-05	3.58E-04	3.39E-03	3.30E-02	1.84E-01	7.14E-01	1.58E+00	1.76E+00	8.98E-02	2.15E-14
AC227	6.35E-09	2.40E-05	1.07E-03	1.56E-03	2.91E-03	7.30E-03	1.72E-02	3.33E-02	3.86E-02	3.87E-02	3.83E-02	3.51E-02
AC228	2.34E-14	9.98E-11	1.88E-09	3.17E-09	7.03E-09	2.20E-08	6.98E-08	2.45E-07	7.42E-07	2.46E-06	2.17E-05	8.13E-05
TH227	5.44E-09	2.17E-05	1.06E-03	1.54E-03	2.87E-03	7.20E-03	1.70E-02	3.28E-02	3.81E-02	3.81E-02	3.78E-02	3.46E-02
TH228	9.49E-06	1.83E-02	9.55E-06	1.45E-08	7.03E-09	2.20E-08	6.98E-08	2.45E-07	7.42E-07	2.46E-06	2.17E-05	8.13E-05
TH229	3.05E-10	6.72E-07	3.07E-05	3.58E-04	3.39E-03	3.30E-02	1.84E-01	7.14E-01	1.58E+00	1.76E+00	8.98E-02	2.15E-14
TH230	3.31E-06	7.29E-03	9.67E-03	1.53E-02	3.11E-02	8.42E-02	2.18E-01	5.23E-01	7.57E-01	6.82E-01	6.57E-01	6.48E-01
TH231	8.02E-03	1.34E-01	3.38E-02	3.39E-02	3.41E-02	3.50E-02	3.66E-02	3.84E-02	3.87E-02	3.87E-02	3.83E-02	3.51E-02
TH232	6.09E-13	1.34E-09	1.88E-09	3.17E-09	7.03E-09	2.20E-08	6.98E-08	2.45E-07	7.42E-07	2.46E-06	2.17E-05	8.13E-05
TH234	2.90E-01	8.28E+01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.57E-01	6.48E-01
PA231	3.91E-07	8.63E-04	1.07E-03	1.56E-03	2.91E-03	7.30E-03	1.72E-02	3.33E-02	3.86E-02	3.87E-02	3.83E-02	3.51E-02
PA233	6.73E-03	3.47E+00	1.81E+00	2.13E+00	2.28E+00	2.28E+00	2.27E+00	2.22E+00	2.08E+00	1.66E+00	8.98E-02	1.98E-14
PA234M	2.90E-01	8.28E+01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.57E-01	6.48E-01
PA234	2.93E-04	8.38E-02	6.58E-04	6.58E-04	6.58E-04	6.58E-04	6.58E-04	6.58E-04	6.58E-04	6.58E-04	6.57E-04	6.48E-04
U232	4.34E-08	1.01E-04	9.30E-06	1.10E-08	4.81E-17	0.	0.	0.	0.	0.	0.	0.
U233	4.29E-09	1.71E-05	2.17E-03	8.15E-03	2.74E-02	9.38E-02	2.73E-01	7.82E-01	1.56E+00	1.76E+00	8.98E-02	2.14E-14
U234	4.12E-04	9.08E-01	9.33E-01	9.37E-01	9.36E-01	9.31E-01	9.16E-01	8.70E-01	7.79E-01	6.75E-01	6.57E-01	6.48E-01
U235	1.53E-05	3.37E-02	3.38E-02	3.39E-02	3.41E-02	3.50E-02	3.66E-02	3.84E-02	3.87E-02	3.87E-02	3.83E-02	3.51E-02
U236	1.66E-05	3.66E-02	3.70E-02	3.80E-02	4.04E-02	4.58E-02	5.02E-02	5.08E-02	5.05E-02	4.95E-02	3.81E-02	2.80E-03
U237	4.00E-05	8.64E-02	7.45E-08	5.62E-09	4.75E-09	2.64E-09	4.94E-10	1.40E-12	7.28E-20	0.	0.	0.

TABLE III-D-2 (Continued)

N REACTOR .947 ENRICHED PROPERTIES OF COLLECTED WASTE

POWER= 10.00MW, BURNUP= 1380.MWD, FLUX= 2.17E+13N/CM**2-SEC

NUCLIDE RADIOACTIVITY, CURIES
BASIS = 2200 TONS .947 ENR N REACTOR WASTE

	CHARGE	SEPARATION	3.0E+02YR	1.0E+03YR	3.0E+03YR	1.0E+04YR	3.0E+04YR	1.0E+05YR	3.0E+05YR	1.0E+06YR	1.0E+07YR	1.0E+08YR
U238	2.99E-04	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.58E-01	6.57E-01	6.48E-01
NP237	6.91E-04	1.52E+00	1.81E+00	2.13E+00	2.25E+00	2.28E+00	2.27E+00	2.22E+00	2.08E+00	1.66E+00	8.98E-02	1.98E-14
NP239	6.53E-04	4.38E+00	4.24E+00	3.98E+00	3.42E+00	1.76E+00	2.88E-01	5.07E-04	7.74E-12	8.51E-13	5.82E-13	1.30E-14
PU238	7.11E-03	3.63E+01	1.05E+01	2.87E-01	2.97E-05	4.10E-19	0.	0.	0.	0.	0.	0.
PU239	6.49E-02	1.43E+02	1.47E+02	1.39E+02	1.32E+02	1.08E+02	5.17E+01	8.46E+00	2.89E-02	6.79E-11	5.82E-13	1.30E-14
PU240	2.30E-02	5.05E+01	4.91E+01	4.57E+01	3.74E+01	1.82E+01	2.34E+00	1.79E-03	2.23E-12	5.08E-16	5.48E-16	2.58E-16
PU241	1.60E+00	3.45E+03	2.98E-03	2.25E-04	1.90E-04	1.06E-04	1.98E-05	5.58E-08	2.91E-15	0.	0.	0.
PU242	3.37E-06	7.32E-03	8.02E-03	8.24E-03	8.22E-03	8.11E-03	7.82E-03	6.88E-03	4.77E-03	1.33E-03	9.46E-11	0.
AM241	1.67E+00	3.68E+03	2.35E+03	7.67E+02	3.12E+01	5.32E-04	1.98E-05	5.58E-08	3.07E-15	0.	0.	0.
AM242M	5.94E-03	1.30E+01	3.32E+00	1.37E-01	1.50E-05	2.07E-19	0.	0.	0.	0.	0.	0.
AM242	5.94E-03	1.31E+01	3.32E+00	1.37E-01	1.59E-05	2.07E-19	0.	0.	0.	0.	0.	0.
AM243	1.98E-03	4.35E+00	4.24E+00	3.98E+00	3.42E+00	1.76E+00	2.88E-01	5.07E-04	7.74E-12	8.51E-13	5.82E-13	1.30E-14
CM242	4.64E+00	6.07E+03	2.73E+00	1.12E-01	1.43E-05	1.70E-19	0.	0.	0.	0.	0.	0.
CM243	1.90E-04	4.14E-01	6.24E-04	1.63E-10	2.52E-29	0.	0.	0.	0.	0.	0.	0.
CM244	1.24E-02	2.69E+01	2.76E-04	6.34E-16	4.54E-21	1.50E-20	4.42E-20	1.38E-19	3.43E-19	6.60E-19	7.12E-19	3.35E-19
CM245	1.11E-07	2.44E-04	2.38E-04	2.24E-04	1.90E-04	1.06E-04	1.97E-05	5.57E-08	2.91E-15	0.	0.	0.
CM246	2.36E-09	5.19E-06	4.96E-06	4.48E-06	3.34E-06	1.19E-06	6.29E-08	2.12E-12	3.54E-25	0.	0.	0.
SUBTOT	8.63E+00	1.37E+04	2.58E+03	9.68E+02	2.14E+02	1.39E+02	7.62E+01	2.79E+01	2.92E+01	2.91E+01	1.06E+01	9.46E+00
TOTAL	8.63E+00	1.37E+04	2.58E+03	9.68E+02	2.14E+02	1.39E+02	7.62E+01	2.79E+01	2.92E+01	2.91E+01	1.06E+01	9.46E+00

TABLE III-D-3 THERMAL POWER BY NUCLIDE, WATTS

N REACTOR .947 ENRICHED PROPERTIES OF COLLECTED WASTE

POWER= 10.00MW. BURNUP= 1380.MWD. FLUX= 2.17E+13N/CM**2-SEC

NUCLIDE THERMAL POWER. WATTS
BASIS = 2200 TONS .947 ENR N REACTOR WASTE

	CHARGE	SEPARATION	1.0E+00YR	2.0E+00YR	3.0E+00YR	5.0E+00YR	1.0E+01YR	1.5E+01YR	2.0E+01YR	3.0E+01YR	5.0E+01YR	1.0E+02YR
H 3	9.33E-04	1.98E+00	1.88E+00	1.77E+00	1.66E+00	1.50E+00	1.13E+00	8.52E-01	6.43E-01	3.66E-01	1.19E-01	7.09E-03
SE 79	6.74E-06	1.48E-02	1.48E-02	1.48E-02	1.48E-02	1.48E-02	1.48E-02	1.48E-02	1.48E-02	1.48E-02	1.48E-02	1.48E-02
RB 87	6.35E-10	1.40E-06	1.40E-06	1.40E-06	1.40E-06	1.40E-06	1.40E-06	1.40E-06	1.40E-06	1.40E-06	1.40E-06	1.40E-06
SR 89	7.27E+01	2.67E+04	2.06E+02	1.58E+00	1.22E-02	7.20E-07	1.94E-17	5.22E-28	1.41E-38	1.02E-59	0.	0.
SR 90	5.09E+00	1.10E+04	1.08E+04	1.05E+04	1.03E+04	9.76E+03	8.63E+03	7.63E+03	6.74E+03	5.27E+03	3.22E+03	9.37E+02
Y 90	2.29E+01	5.00E+04	4.84E+04	4.72E+04	4.61E+04	4.39E+04	3.88E+04	3.43E+04	3.03E+04	2.37E+04	1.45E+04	4.21E+03
Y 91	1.25E+02	5.19E+04	7.00E+02	9.46E+00	1.28E-01	2.33E-05	1.05E-14	4.70E-24	2.11E-33	4.27E-52	0.	0.
ZR 93	1.04E-05	2.29E-02	2.29E-02	2.29E-02	2.29E-02	2.29E-02	2.29E-02	2.29E-02	2.29E-02	2.29E-02	2.29E-02	2.29E-02
NB 93M	5.77E-07	2.28E-03	3.87E-03	5.38E-03	6.82E-03	9.46E-03	1.51E-02	1.94E-02	2.27E-02	2.73E-02	3.18E-02	3.41E-02
ZR 95	2.38E+02	1.09E+05	2.22E+03	4.51E+01	9.19E-01	3.81E-04	1.33E-12	4.67E-21	1.63E-29	2.00E-46	0.	0.
NB 95M	1.36E+00	6.38E+02	1.25E+01	2.55E-01	5.19E-03	2.15E-06	7.53E-15	2.64E-23	9.23E-32	1.13E-48	0.	0.
NB 95	4.26E+02	2.05E+05	4.52E+03	9.23E+01	1.88E+00	7.60E-04	2.66E-12	9.32E-21	3.26E-29	4.00E-46	0.	0.
TC 99	4.30E-04	9.46E-01	9.46E-01	9.46E-01	9.46E-01	9.46E-01	9.46E-01	9.46E-01	9.46E-01	9.46E-01	9.46E-01	9.46E-01
RU103	2.81E+01	7.89E+03	1.32E+01	2.21E-02	3.71E-05	1.04E-10	1.37E-24	1.81E-38	2.39E-52	0.	0.	0.
RH103M	4.05E+00	1.14E+03	1.90E+00	3.19E-03	5.34E-06	1.50E-11	1.98E-25	2.61E-39	3.45E-53	0.	0.	0.
RU106	9.32E-01	1.38E+03	6.94E+02	3.48E+02	1.75E+02	4.40E+01	1.40E+00	4.45E-02	1.41E-03	1.43E-06	1.46E-12	1.54E-27
RH106	1.65E+02	2.45E+05	1.23E+05	6.19E+04	3.10E+04	7.80E+03	2.48E+02	7.89E+00	2.51E-01	2.54E-04	2.59E-10	2.74E-25
PD107	1.90E-07	4.19E-04	4.19E-04	4.19E-04	4.19E-04	4.19E-04	4.19E-04	4.19E-04	4.19E-04	4.19E-04	4.19E-04	4.19E-04
AG109M	2.21E-13	3.52E-10	2.01E-10	1.15E-10	6.58E-11	2.15E-11	1.32E-12	8.06E-14	4.93E-15	1.65E-17	2.59E-22	1.91E-34
CD109	2.11E-13	3.36E-10	1.92E-10	1.10E-10	6.28E-11	2.05E-11	1.26E-12	7.69E-14	4.71E-15	1.76E-17	2.47E-22	1.82E-34
AG110M	7.41E-02	9.39E+01	3.45E+01	1.27E+01	4.67E+00	6.31E+01	4.24E-03	2.85E-05	1.92E-07	8.67E-12	1.77E-20	0.
AG110	4.14E-03	5.24E+00	1.93E+00	7.09E-01	2.61E-01	3.52E-02	2.37E-04	1.59E-06	1.07E-08	4.84E-13	9.89E-22	0.
CD113M	1.39E-05	2.97E-02	2.82E-02	2.69E-02	2.56E-02	2.32E-02	1.81E-02	1.41E-02	1.10E-02	6.72E-03	2.50E-03	2.10E-04
SN119M	7.33E-04	9.23E-01	3.35E-01	1.22E-01	4.43E-02	5.84E-03	3.70E-05	2.34E-07	1.48E-09	5.94E-14	9.55E-23	0.
SN121M	1.54E-09	3.38E-06	3.35E-06	3.32E-06	3.29E-06	3.23E-06	3.08E-06	2.95E-06	2.81E-06	2.57E-06	2.14E-06	1.36E-06
SN123	1.11E+00	9.01E+02	1.19E+02	1.57E+01	2.07E+00	3.61E-02	1.45E-06	5.80E-11	2.32E-15	3.74E-24	9.64E-42	0.
TE123M	2.88E-07	2.22E-04	2.55E-05	2.93E-06	3.37E-07	4.45E-09	8.94E-14	1.79E-18	3.60E-23	1.45E-32	2.34E-51	0.
SB124	2.96E-03	1.25E+00	1.84E-02	2.71E-04	3.99E-06	8.66E-10	5.96E-19	4.13E-28	2.86E-37	1.36E-55	0.	0.
SB125	1.07E+00	2.02E+03	1.56E+03	1.21E+03	9.34E+02	5.59E+02	1.55E+02	4.29E+01	1.19E+01	9.14E-01	5.39E-03	1.44E-08
TE125M	1.76E-01	3.49E+02	2.74E+02	2.12E+02	1.64E+02	9.82E+01	2.72E+01	7.54E+00	2.09E+00	1.61E-01	9.46E-04	2.53E-09
SN126	1.55E-05	3.41E-02	3.41E-02	3.41E-02	3.41E-02	3.41E-02	3.41E-02	3.41E-02	3.41E-02	3.41E-02	3.41E-02	3.41E-02
SB126M	9.72E-05	2.14E-01	2.14E-01	2.14E-01	2.14E-01	2.14E-01	2.14E-01	2.14E-01	2.14E-01	2.14E-01	2.14E-01	2.14E-01
SB126	1.87E-04	4.08E-01	4.08E-01	4.08E-01	4.08E-01	4.08E-01	4.07E-01	4.07E-01	4.07E-01	4.07E-01	4.07E-01	4.07E-01
TE127M	2.91E-01	2.12E+02	2.14E+01	2.04E+00	2.00E-01	1.92E-03	1.74E-08	1.58E-13	1.43E-18	1.18E-28	7.96E-49	0.
TE127	8.41E-01	6.14E+02	6.30E+01	5.88E+00	5.77E-01	5.55E-03	5.03E-08	4.56E-13	4.14E-18	3.40E-28	2.30E-48	0.
I129	1.83E-07	4.04E-04	4.05E-04	4.05E-04	4.05E-04	4.05E-04	4.05E-04	4.05E-04	4.05E-04	4.05E-04	4.05E-04	4.05E-04
CS134	7.15E+00	1.29E+04	9.19E+03	6.55E+03	4.67E+03	2.38E+03	4.38E+02	8.09E+01	1.49E+01	5.08E-01	5.88E-04	2.68E-11
CS135	4.84E-06	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.06E-02
CS137	7.34E+00	1.60E+04	1.56E+04	1.53E+04	1.49E+04	1.42E+04	1.27E+04	1.13E+04	1.01E+04	7.99E+03	5.03E+03	1.59E+03
BA137M	1.65E+01	3.59E+04	3.51E+04	3.43E+04	3.35E+04	3.20E+04	2.85E+04	2.54E+04	2.26E+04	1.79E+04	1.13E+04	3.56E+03
CE144	6.34E+01	8.49E+04	3.48E+04	1.43E+04	5.85E+03	9.85E+02	1.14E+01	1.33E-01	1.54E-03	2.07E-07	3.76E-15	1.67E-34
PR144	6.01E+02	8.04E+05	3.30E+05	1.35E+05	5.54E+04	9.33E+03	1.08E+02	1.26E+00	1.46E-02	1.96E-06	3.56E-14	1.56E-33
PM147	8.02E+00	1.51E+04	1.16E+04	8.88E+03	6.82E+03	4.02E+03	1.07E+03	2.85E+02	7.60E+01	5.39E+00	2.72E-02	4.91E-08
PM148M	1.17E+00	3.48E+02	8.39E-01	2.03E-03	4.89E-06	2.85E-11	2.33E-24	1.91E-37	1.57E-50	0.	0.	0.
PM148	6.14E-02	1.83E+01	4.41E-02	1.06E-04	2.57E-07	1.50E-12	1.23E-25	1.01E-38	8.24E-52	0.	0.	0.
SM151	1.95E-01	4.27E+02	4.23E+02	4.20E+02	4.17E+02	4.10E+02	3.94E+02	3.79E+02	3.64E+02	3.36E+02	2.87E+02	1.92E+02
EU152	4.73E-03	1.00E+01	9.48E+00	8.95E+00	8.45E+00	7.53E+00	5.64E+00	4.23E+00	3.17E+00	1.78E+00	5.60E-01	3.12E-02
GD153	2.66E-05	3.30E-02	1.16E-02	4.07E-03	1.43E-03	1.77E-04	9.46E-07	5.06E-09	2.71E-11	7.78E-16	6.40E-25	0.
EU154	1.45E-01	3.11E+02	2.98E+02	2.85E+02	2.73E+02	2.50E+02	2.02E+02	1.62E+02	1.31E+02	8.48E+01	3.56E+01	4.09E+00
EU155	1.88E-01	3.29E+02	2.24E+02	1.53E+02	1.04E+02	4.85E+01	7.16E+00	1.06E+00	1.56E-01	3.38E-03	1.60E-06	7.76E-15
TB160	6.49E-03	3.27E+00	9.77E-02	2.92E-03	8.73E-05	7.79E-08	1.86E-15	4.42E-23	1.05E-30	5.97E-46	0.	0.
HO166M	1.30E-09	2.86E-06	2.85E-06	2.85E-06	2.85E-06	2.85E-06	2.84E-06	2.83E-06	2.82E-06	2.81E-06	2.77E-06	2.70E-06
SUBTOT	1.80E+03	1.68E+06	6.30E+05	3.37E+05	2.11E+05	1.26E+05	9.12E+04	7.95E+04	7.03E+04	5.53E+04	3.43E+04	1.05E+04
TOTAL	1.81E+03	1.69E+06	6.30E+05	3.37E+05	2.11E+05	1.26E+05	9.12E+04	7.95E+04	7.03E+04	5.53E+04	3.43E+04	1.05E+04

TABLE III-D-3 (Continued)

N REACTOR .947 ENRICHED PROPERTIES OF COLLECTED WASTE

POWER= 10.00MW, BURNUP= 1380.MWD, FLUX= 2.17E+13N/CM**2-SEC

NUCLIDE THERMAL POWER, WATTS
BASIS = 2200 TONS .947 ENR N REACTOR WASTE

	CHARGE	SEPARATION	3.0E+02YR	1.0E+03YR	3.0E+03YR	1.0E+04YR	3.0E+04YR	1.0E+05YR	3.0E+05YR	1.0E+06YR	1.0E+07YR	1.0E+08YR
H 3	9.33E-04	2.01E+00	9.18E-08	6.84E-25	0.	0.	0.	0.	0.	0.	0.	0.
SE 79	6.74E-06	1.48E-02	1.48E-02	1.47E-02	1.44E-02	1.33E-02	1.09E-02	5.11E-03	6.05E-04	3.47E-07	0.	0.
RB 87	6.35E-10	1.40E-06	1.40E-06	1.40E-06	1.40E-06	1.40E-06	1.40E-06	1.40E-06	1.40E-06	1.40E-06	1.40E-06	1.39E-06
SR 90	5.09E+00	1.11E+04	6.80E+00	2.16E-07	8.21E-29	0.	0.	0.	0.	0.	0.	0.
Y 90	2.29E+01	4.99E+04	3.06E+01	9.72E-07	3.69E-28	0.	0.	0.	0.	0.	0.	0.
ZR 93	1.04E-05	2.29E-02	2.29E-02	2.28E-02	2.26E-02	2.28E-02	2.25E-02	2.18E-02	1.99E-02	1.44E-02	2.25E-04	1.97E-22
NB 93M	5.77E-07	1.88E-03	3.43E-02	3.43E-02	3.42E-02	3.41E-02	3.38E-02	3.27E-02	2.98E-02	2.16E-02	3.38E-04	2.96E-22
TC 99	4.30E-04	9.46E-01	9.45E-01	9.43E-01	9.37E-01	9.16E-01	8.58E-01	6.82E-01	3.55E-01	3.60E-02	6.02E-15	0.
PD107	1.90E-07	4.19E-04	4.19E-04	4.19E-04	4.19E-04	4.18E-04	4.18E-04	4.15E-04	4.07E-04	3.79E-04	1.56E-04	2.10E-08
CD113M	1.39E-05	3.00E-02	1.07E-08	9.55E-24	0.	0.	0.	0.	0.	0.	0.	0.
SN121M	1.54E-09	3.39E-06	2.20E-07	3.71E-10	4.46E-18	0.	0.	0.	0.	0.	0.	0.
SN126	1.55E-05	3.41E-02	3.41E-02	3.39E-02	3.34E-02	3.18E-02	2.77E-02	1.71E-02	4.27E-03	3.34E-05	0.	0.
SB126M	9.72E-05	2.14E-01	2.13E-01	2.12E-01	2.09E-01	1.99E-01	1.74E-01	1.07E-01	2.67E-02	2.09E-04	0.	0.
SB126	1.87E-04	4.08E-01	4.07E-01	4.05E-01	3.99E-01	3.80E-01	3.31E-01	2.04E-01	5.10E-02	3.99E-04	0.	0.
I129	1.83E-07	4.04E-04	4.05E-04	4.05E-04	4.05E-04	4.05E-04	4.04E-04	4.03E-04	4.00E-04	3.89E-04	2.69E-04	6.87E-06
CS135	4.84E-06	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.04E-02	9.93E-03	8.45E-03	1.06E-03	9.88E-13
CS137	7.36E+00	1.61E+04	1.57E+01	1.49E-06	1.24E-26	0.	0.	0.	0.	0.	0.	0.
BA137M	1.65E+01	3.61E+04	3.53E+01	3.35E-06	2.84E-26	0.	0.	0.	0.	0.	0.	0.
SM151	1.95E-01	4.28E+02	3.92E+01	1.48E-01	1.79E-08	0.	0.	0.	0.	0.	0.	0.
EU152	4.73E-03	1.02E+01	3.05E-07	8.47E-25	0.	0.	0.	0.	0.	0.	0.	0.
EU154	1.45E-01	3.14E+02	7.15E-04	4.86E-17	0.	0.	0.	0.	0.	0.	0.	0.
HO166M	1.30E-09	2.86E-06	2.40E-06	1.60E-06	5.05E-07	8.87E-09	8.54E-14	2.37E-31	0.	0.	0.	0.
SUBTOT	5.22E+01	1.14E+05	1.29E+02	1.83E+00	1.66E+00	1.61E+00	1.47E+00	1.08E+00	4.98E-01	8.19E-02	2.05E-03	8.28E-06
TOTAL	1.81E+03	2.15E+06	1.29E+02	1.83E+00	1.66E+00	1.61E+00	1.47E+00	1.08E+00	4.98E-01	8.19E-02	2.05E-03	8.28E-06

TABLE III-D-3 (Continued)

N REACTOR .947 ENRICHED PROPERTIES OF COLLECTED WASTE

POWER= 10.00MW, BURNUP= 1380.MWD, FLUX= 2.17E+13N/CM**2-SEC

NUCLIDE THERMAL POWER, WATTS
BASIS = 6200 TONS .947 ENR N REACTOR WASTE

	CHARGE	SEPARATION	1.0E+00YR	2.0E+00YR	3.0E+00YR	5.0E+00YR	1.0E+01YR	1.5E+01YR	2.0E+01YR	3.0E+01YR	5.0E+01YR	1.0E+02YR
TL207	1.51E-11	8.25E-08	1.71E-07	2.48E-07	3.23E-07	4.65E-07	7.84E-07	1.06E-06	1.29E-06	1.67E-06	2.15E-06	2.65E-06
TL208	8.17E-08	1.45E-04	9.92E-05	6.93E-05	4.86E-05	2.41E-05	4.95E-06	1.82E-06	1.27E-06	1.08E-06	8.87E-07	5.48E-07
TL209	9.61E-14	2.41E-10	2.43E-10	2.44E-10	2.45E-10	2.48E-10	2.60E-10	2.78E-10	3.01E-10	3.65E-10	5.60E-10	1.45E-09
PB209	2.92E-13	7.70E-10	7.76E-10	7.79E-10	7.83E-10	7.93E-10	8.32E-10	8.89E-10	9.63E-10	1.17E-09	1.79E-09	4.64E-09
PB210	2.76E-14	2.88E-12	9.49E-12	2.01E-11	3.47E-11	7.50E-11	2.36E-10	4.73E-10	7.74E-10	1.53E-09	3.49E-09	9.04E-09
PB211	1.68E-11	9.15E-08	1.90E-07	2.75E-07	3.56E-07	5.16E-07	8.70E-07	1.17E-06	1.43E-06	1.85E-06	2.39E-06	2.94E-06
PB212	1.37E-08	2.47E-05	1.70E-05	1.19E-05	8.31E-06	4.12E-06	8.46E-07	3.11E-07	2.18E-07	1.84E-07	1.52E-07	9.37E-08
PB214	1.62E-12	8.35E-09	1.60E-08	2.37E-08	3.14E-08	4.68E-08	8.54E-08	1.24E-07	1.63E-07	2.41E-07	3.99E-07	8.01E-07
BI210	1.74E-14	1.78E-12	6.02E-10	1.28E-09	2.20E-09	4.76E-09	1.50E-08	3.00E-08	4.91E-08	9.73E-08	2.22E-07	6.12E-07
BI211	1.96E-10	1.07E-06	2.21E-06	3.21E-06	4.17E-06	6.01E-06	1.01E-05	1.37E-05	1.67E-05	2.15E-05	2.78E-05	3.42E-05
BI212	1.69E-07	2.99E-04	2.05E-04	1.44E-04	1.01E-04	4.99E-05	1.02E-05	3.76E-06	2.63E-06	2.23E-06	1.84E-06	1.13E-06
BI213	1.64E-12	4.11E-09	4.15E-09	4.16E-09	4.19E-09	4.24E-09	4.45E-09	4.75E-09	5.15E-09	6.23E-09	9.57E-09	2.48E-08
BI214	9.28E-12	4.77E-08	9.14E-08	1.35E-07	1.79E-07	2.67E-07	4.88E-07	7.10E-07	9.32E-07	1.38E-06	2.28E-06	4.58E-06
PO210	6.40E-14	1.06E-09	4.46E-09	1.38E-08	2.01E-08	4.75E-08	1.79E-07	3.59E-07	5.87E-07	1.16E-06	2.65E-06	7.31E-06
PO211	6.66E-13	3.63E-09	7.53E-09	1.09E-08	1.42E-08	2.04E-08	3.45E-08	4.65E-08	5.66E-08	7.33E-08	9.46E-08	1.16E-07
PO212	3.30E-07	5.85E-04	4.01E-04	2.80E-04	1.96E-04	9.75E-05	2.00E-05	7.35E-06	5.15E-06	4.35E-06	3.59E-06	2.22E-06
PO213	1.31E-11	3.25E-08	3.28E-08	3.29E-08	3.31E-08	3.35E-08	3.51E-08	3.75E-08	4.07E-08	4.93E-08	7.56E-08	1.96E-07
PO214	3.04E-11	1.56E-07	2.99E-07	4.43E-07	5.87E-07	8.75E-07	1.60E-06	2.32E-06	3.05E-06	4.51E-06	7.46E-06	1.50E-05
PO215	2.20E-10	1.20E-06	2.49E-06	3.61E-06	4.69E-06	6.76E-06	1.14E-05	1.54E-05	1.88E-05	2.42E-05	3.13E-05	3.85E-05
PO216	3.90E-07	7.04E-04	4.84E-04	3.38E-04	2.37E-04	1.18E-04	2.41E-05	8.87E-06	6.21E-06	5.25E-06	4.33E-06	2.67E-06
PO218	2.41E-11	1.24E-07	2.38E-07	3.52E-07	4.67E-07	6.96E-07	1.27E-06	1.85E-06	2.42E-06	3.59E-06	5.93E-06	1.19E-05
AT217	1.12E-11	2.80E-08	2.83E-08	2.84E-08	2.85E-08	2.89E-08	3.03E-08	3.24E-08	3.51E-08	4.25E-08	6.52E-08	1.69E-07
RN219	2.03E-10	1.11E-06	2.30E-06	3.33E-06	4.34E-06	6.25E-06	1.05E-05	1.42E-05	1.74E-05	2.24E-05	2.89E-05	3.56E-05
RN220	3.62E-07	6.52E-04	4.49E-04	3.14E-04	2.20E-04	1.09E-04	2.24E-05	8.22E-06	5.75E-06	4.87E-06	4.01E-06	2.48E-06
RN222	2.17E-11	1.12E-07	2.14E-07	3.17E-07	4.20E-07	6.26E-07	1.14E-06	1.66E-06	2.18E-06	3.22E-06	5.33E-06	1.07E-05
FR221	9.94E-12	2.49E-08	2.51E-08	2.52E-08	2.53E-08	2.57E-08	2.69E-08	2.87E-08	3.12E-08	3.77E-08	5.79E-08	1.50E-07
FR223	2.08E-13	9.99E-10	1.86E-09	2.70E-09	3.51E-09	5.05E-09	8.52E-09	1.15E-08	1.40E-08	1.81E-08	2.34E-08	2.88E-08
RA223	1.78E-10	9.51E-07	1.97E-06	2.86E-06	3.72E-06	5.36E-06	9.04E-06	1.22E-05	1.49E-05	1.92E-05	2.48E-05	3.05E-05
RA224	3.26E-07	5.89E-04	4.05E-04	2.83E-04	1.98E-04	9.83E-05	2.02E-05	7.41E-06	5.19E-06	4.39E-06	3.62E-06	2.23E-06
RA225	1.84E-13	4.41E-10	4.44E-10	4.46E-10	4.48E-10	4.54E-10	4.76E-10	5.09E-10	5.51E-10	6.67E-10	1.02E-09	2.66E-09
RA226	1.90E-11	9.65E-08	1.86E-07	2.75E-07	3.65E-07	5.44E-07	9.92E-07	1.44E-06	1.89E-06	2.80E-06	4.63E-06	9.31E-06
AC225	9.17E-12	2.30E-08	2.32E-08	2.33E-08	2.34E-08	2.37E-08	2.48E-08	2.65E-08	2.88E-08	3.48E-08	5.34E-08	1.39E-07
AC227	3.20E-12	1.53E-08	2.86E-08	4.14E-08	5.39E-08	7.76E-08	1.31E-07	1.77E-07	2.16E-07	2.78E-07	3.59E-07	4.43E-07
AC228	1.24E-15	6.91E-13	1.32E-12	1.89E-12	2.41E-12	3.29E-12	4.87E-12	5.82E-12	6.41E-12	7.02E-12	7.46E-12	7.98E-12
TH227	1.87E-10	9.69E-07	1.93E-06	2.79E-06	3.63E-06	5.24E-06	8.63E-06	1.19E-05	1.46E-05	1.88E-05	2.42E-05	2.98E-05
TH228	3.11E-07	5.53E-04	3.86E-04	2.69E-04	1.89E-04	9.37E-05	1.92E-05	7.08E-06	4.96E-06	4.20E-06	3.46E-06	2.14E-06
TH229	9.22E-12	2.03E-08	2.04E-08	2.05E-08	2.06E-08	2.09E-08	2.19E-08	2.34E-08	2.53E-08	3.07E-08	4.71E-08	1.22E-07
TH230	9.35E-06	2.06E-04	2.06E-04	2.06E-04	2.07E-04	2.07E-04	2.08E-04	2.09E-04	2.10E-04	2.13E-04	2.17E-04	2.28E-04
TH231	6.32E-06	7.43E-05	2.66E-05	2.66E-05	2.66E-05	2.66E-05	2.66E-05	2.66E-05	2.66E-05	2.66E-05	2.66E-05	2.66E-05
TH232	1.47E-14	3.24E-11	3.25E-11	3.25E-11	3.26E-11	3.26E-11	3.29E-11	3.31E-11	3.33E-11	3.37E-11	3.46E-11	3.68E-11
TH234	1.03E-04	1.78E-02	2.34E-04	2.34E-04	2.34E-04	2.34E-04	2.34E-04	2.34E-04	2.34E-04	2.34E-04	2.34E-04	2.34E-04
PA231	1.19E-08	2.63E-05	2.64E-05	2.64E-05	2.64E-05	2.64E-05	2.65E-05	2.67E-05	2.68E-05	2.70E-05	2.74E-05	2.85E-05
PA233	9.10E-06	3.64E-03	2.06E-03	2.06E-03	2.06E-03	2.06E-03	2.07E-03	2.08E-03	2.09E-03	2.10E-03	2.13E-03	2.21E-03
PA234M	1.49E-03	2.58E-01	3.39E-03	3.38E-03	3.38E-03	3.38E-03	3.38E-03	3.38E-03	3.38E-03	3.38E-03	3.38E-03	3.38E-03
PA234	2.67E-06	4.61E-04	5.99E-06	5.98E-06	5.98E-06	5.98E-06	5.98E-06	5.98E-06	5.98E-06	5.98E-06	5.98E-06	5.98E-06
U232	1.39E-09	3.34E-06	3.72E-06	4.01E-06	4.23E-06	4.50E-06	4.68E-06	4.57E-06	4.39E-06	4.00E-06	3.30E-06	2.04E-06
U233	1.25E-10	5.54E-07	7.80E-07	9.90E-07	1.20E-06	1.60E-06	2.55E-06	3.51E-06	4.47E-06	6.40E-06	1.03E-05	2.03E-05
U234	1.19E-05	2.61E-02	2.61E-02	2.61E-02	2.61E-02	2.62E-02	2.62E-02	2.62E-02	2.62E-02	2.63E-02	2.64E-02	2.65E-02
U235	4.26E-07	9.36E-04	9.36E-04	9.36E-04	9.36E-04	9.36E-04	9.36E-04	9.36E-04	9.36E-04	9.36E-04	9.36E-04	9.37E-04
U236	4.51E-07	9.92E-04	9.92E-04	9.92E-04	9.92E-04	9.92E-04	9.92E-04	9.93E-04	9.93E-04	9.93E-04	9.94E-04	9.96E-04
U237	2.66E-08	5.67E-05	5.41E-05	5.16E-05	4.93E-05	4.49E-05	3.55E-05	2.81E-05	2.22E-05	1.39E-05	5.46E-06	5.25E-07
U238	7.56E-06	1.66E-02	1.66E-02	1.66E-02	1.66E-02	1.66E-02	1.66E-02	1.66E-02	1.66E-02	1.66E-02	1.66E-02	1.66E-02

9 1 1 1 3 9 1 1 5 0 2

TABLE III-D-3 (Continued)

N REACTOR .947 ENRICHED PROPERTIES OF COLLECTED WASTE

POWER= 10.00MW, BURNUP= 1380.MWD, FLUX= 2.17E+13N/CM**2-SEC

NUCLIDE THERMAL POWER, WATTS
BASIS = 200 TONS .947 ENR N REACTOR WASTE

	CHARGE	SEPARATION	1.0E+00YR	2.0E+00YR	3.0E+00YR	5.0E+00YR	1.0E+01YR	1.5E+01YR	2.0E+01YR	3.0E+01YR	5.0E+01YR	1.0E+02YR
NP237	2.03E-05	4.47E-02	4.47E-02	4.47E-02	4.48E-02	4.48E-02	4.50E-02	4.52E-02	4.54E-02	4.57E-02	4.64E-02	4.80E-02
NP239	8.83E-07	5.90E-03	5.88E-03	5.88E-03	5.88E-03	5.88E-03	5.88E-03	5.88E-03	5.87E-03	5.87E-03	5.86E-03	5.83E-03
PU236	2.77E-08	5.26E-05	4.13E-05	3.24E-05	2.54E-05	1.56E-05	4.63E-06	1.37E-06	4.07E-07	3.57E-08	2.76E-10	1.45E-15
PU238	2.35E-06	1.45E+00	2.03E+00	2.15E+00	2.16E+00	2.14E+00	2.07E+00	2.00E+00	1.94E+00	1.82E+00	1.60E+00	1.16E+00
PU239	2.02E-03	4.44E+00	4.44E+00	4.44E+00	4.44E+00	4.44E+00	4.44E+00	4.44E+00	4.44E+00	4.44E+00	4.43E+00	4.43E+00
PU240	7.15E-04	1.57E+00	1.57E+00	1.57E+00	1.57E+00	1.57E+00	1.57E+00	1.57E+00	1.57E+00	1.57E+00	1.57E+00	1.56E+00
PU241	6.62E-05	1.42E-01	1.35E-01	1.29E-01	1.23E-01	1.12E-01	8.86E-02	7.01E-02	5.55E-02	3.47E-02	1.36E-02	1.31E-03
PU242	9.82E-08	2.16E-04	2.15E-04	2.16E-04	2.16E-04	2.17E-04	2.17E-04	2.18E-04	2.18E-04	2.20E-04	2.22E-04	2.26E-04
AM241	5.58E-02	1.23E+02	1.23E+02	1.23E+02	1.23E+02	1.23E+02	1.22E+02	1.22E+02	1.21E+02	1.20E+02	1.17E+02	1.08E+02
AM242M	1.69E-06	3.71E-03	3.69E-03	3.68E-03	3.66E-03	3.63E-03	3.54E-03	3.46E-03	3.39E-03	3.23E-03	2.95E-03	2.35E-03
AM242	7.92E-06	1.74E-02	1.73E-02	1.72E-02	1.71E-02	1.70E-02	1.66E-02	1.62E-02	1.59E-02	1.52E-02	1.38E-02	1.10E-02
AM243	7.23E-05	1.59E-01	1.59E-01	1.59E-01	1.59E-01	1.59E-01	1.59E-01	1.59E-01	1.59E-01	1.59E-01	1.58E-01	1.58E-01
CM242	1.71E-01	1.68E+02	3.59E+01	7.91E+00	1.98E+00	4.57E-01	3.77E-01	3.68E-01	3.60E-01	3.44E-01	3.14E-01	2.50E-01
CM243	6.97E-06	1.51E-02	1.48E-02	1.45E-02	1.42E-02	1.36E-02	1.22E-02	1.09E-02	9.81E-03	7.90E-03	5.13E-03	1.74E-03
CM244	4.34E-04	9.33E-01	8.98E-01	8.64E-01	8.31E-01	7.70E-01	6.34E-01	5.25E-01	4.34E-01	2.96E-01	1.37E-01	2.03E-02
CM245	3.48E-09	7.66E-06	7.66E-06	7.66E-06	7.66E-06	7.66E-06	7.65E-06	7.65E-06	7.65E-06	7.64E-06	7.63E-06	7.60E-06
CM246	7.74E-11	1.70E-07	1.70E-07	1.70E-07	1.70E-07	1.70E-07	1.70E-07	1.70E-07	1.70E-07	1.69E-07	1.69E-07	1.68E-07
SUBTOT	2.32E-01	3.00E+02	1.68E+02	1.40E+02	1.34E+02	1.32E+02	1.32E+02	1.31E+02	1.30E+02	1.29E+02	1.25E+02	1.16E+02
TOTAL	2.32E-01	3.00E+02	1.69E+02	1.40E+02	1.34E+02	1.32E+02	1.32E+02	1.31E+02	1.30E+02	1.29E+02	1.25E+02	1.16E+02

TABLE III-D-3 (Continued)

N REACTOR .947 ENRICHED PROPERTIES OF COLLECTED WASTE

POWER= 10.00MW. BURNUP= 1380.MWD. FLUX= 2.17E+13N/CM**2-SEC

NUCLIDE THERMAL POWER, WATTS
BASIS = 2200 TONS .947 ENR N REACTOR WASTE

	CHARGE	SEPARATION	3.0E+02YR	1.0E+03YR	3.0E+03YR	1.0E+04YR	3.0E+04YR	1.0E+05YR	3.0E+05YR	1.0E+06YR	1.0E+07YR	1.0E+08YR
TL207	1.51E-11	6.29E-08	3.23E-06	4.70E-06	8.78E-06	2.20E-05	5.19E-05	1.00E-04	1.16E-04	1.17E-04	1.16E-04	1.06E-04
TL208	8.17E-08	1.55E-04	8.01E-08	1.22E-10	5.85E-11	1.84E-10	5.85E-10	2.05E-09	6.22E-09	2.06E-08	1.82E-07	6.81E-07
TL209	9.61E-14	2.39E-10	1.10E-08	1.29E-07	1.22E-06	1.19E-05	6.64E-05	2.57E-04	5.67E-04	6.33E-04	3.23E-05	7.72E-18
PB209	2.92E-13	7.63E-10	3.53E-08	4.11E-07	3.90E-06	3.79E-05	2.12E-04	8.21E-04	1.81E-03	2.02E-03	1.03E-04	2.47E-17
PB210	2.76E-16	1.73E-12	4.31E-08	1.69E-07	6.56E-07	2.78E-06	9.09E-06	2.18E-05	3.15E-05	2.83E-05	2.72E-05	2.69E-05
PB211	1.68E-11	6.97E-08	3.59E-06	5.21E-06	9.74E-06	2.44E-05	5.76E-05	1.11E-04	1.29E-04	1.29E-04	1.28E-04	1.17E-04
PB212	1.37E-08	2.65E-05	1.37E-08	2.08E-11	1.01E-11	3.15E-11	1.00E-10	3.51E-10	1.06E-09	3.53E-09	3.11E-08	1.17E-07
PB214	1.62E-12	6.32E-09	2.53E-06	9.90E-06	3.85E-05	1.63E-04	5.34E-04	1.28E-03	1.85E-03	1.66E-03	1.60E-03	1.58E-03
BI210	1.74E-14	1.06E-10	2.73E-06	1.07E-05	4.16E-05	1.76E-04	5.77E-04	1.38E-03	2.00E-03	1.80E-03	1.73E-03	1.70E-03
BI211	1.96E-10	8.12E-07	4.18E-05	6.07E-05	1.13E-04	2.84E-04	6.71E-04	1.30E-03	1.50E-03	1.51E-03	1.49E-03	1.37E-03
BI212	1.69E-07	3.21E-04	1.66E-07	2.52E-10	1.22E-10	3.81E-10	1.21E-09	4.25E-09	1.29E-08	4.27E-08	3.77E-07	1.41E-06
BI213	1.64E-12	4.08E-09	1.88E-07	2.20E-06	2.06E-05	2.03E-04	1.13E-03	4.39E-03	9.69E-03	1.08E-02	5.52E-04	1.32E-16
BI214	9.28E-12	3.61E-08	1.44E-05	5.66E-05	2.20E-04	9.33E-04	3.05E-03	7.32E-03	1.06E-02	9.50E-03	9.14E-03	9.02E-03
PO210	6.40E-14	5.42E-10	3.27E-05	1.28E-04	4.98E-04	2.11E-03	6.89E-03	1.65E-02	2.39E-02	2.15E-02	2.07E-02	2.04E-02
PO211	6.66E-13	2.76E-09	1.42E-07	2.06E-07	3.86E-07	9.68E-07	2.28E-06	4.41E-06	5.11E-06	5.12E-06	5.08E-06	4.65E-06
PO212	3.30E-07	6.27E-04	3.24E-07	4.92E-10	2.38E-10	7.45E-10	2.37E-09	8.30E-09	2.52E-08	8.35E-08	7.36E-07	2.76E-06
PO213	1.30E-11	3.22E-08	1.49E-06	1.74E-05	1.65E-04	1.60E-03	8.96E-03	3.47E-02	7.65E-02	8.55E-02	4.36E-03	1.04E-15
PO214	3.04E-11	1.18E-07	4.73E-05	1.85E-04	7.20E-04	3.05E-03	9.98E-03	2.39E-02	3.46E-02	3.11E-02	2.99E-02	2.95E-02
PO215	2.20E-10	9.13E-07	4.70E-05	6.83E-05	1.28E-04	3.20E-04	7.55E-04	1.46E-03	1.69E-03	1.69E-03	1.68E-03	1.54E-03
PO216	3.90E-07	7.54E-04	3.91E-07	5.93E-10	2.88E-10	8.98E-10	2.86E-09	1.00E-08	3.04E-08	1.01E-07	8.88E-07	3.32E-06
PO218	2.41E-11	9.39E-08	3.76E-05	1.47E-04	5.73E-04	2.43E-03	7.93E-03	1.90E-02	2.75E-02	2.47E-02	2.38E-02	2.35E-02
AT217	1.12E-11	2.78E-08	1.28E-06	1.50E-05	1.42E-04	1.38E-03	7.73E-03	2.99E-02	6.61E-02	7.38E-02	3.76E-03	8.99E-16
RN219	2.03E-10	8.44E-07	4.34E-05	6.31E-05	1.18E-04	2.96E-04	6.98E-04	1.35E-03	1.56E-03	1.56E-03	1.55E-03	1.42E-03
RN220	3.62E-07	6.99E-04	3.62E-07	5.50E-10	2.67E-10	8.32E-10	2.65E-09	9.28E-09	2.81E-08	9.33E-08	8.23E-07	3.08E-06
RN222	2.17E-11	8.45E-08	3.38E-05	1.32E-04	5.15E-04	2.18E-03	7.14E-03	1.71E-02	2.47E-02	2.22E-02	2.14E-02	2.11E-02
FR221	9.94E-12	2.47E-08	1.14E-06	1.33E-05	1.26E-04	1.23E-03	6.86E-03	2.65E-02	5.86E-02	6.55E-02	3.34E-03	7.98E-16
FR223	2.08E-13	7.85E-10	3.52E-08	5.11E-08	9.55E-08	2.39E-07	5.65E-07	1.09E-06	1.27E-06	1.27E-06	1.26E-06	1.15E-06
RA223	1.75E-10	7.24E-07	3.73E-05	5.41E-05	1.01E-04	2.54E-04	5.99E-04	1.16E-03	1.34E-03	1.34E-03	1.33E-03	1.22E-03
RA224	3.26E-07	6.30E-04	3.27E-07	4.96E-10	2.40E-10	7.51E-10	2.39E-09	8.37E-09	2.54E-08	8.42E-08	7.43E-07	2.78E-06
RA225	1.86E-13	4.39E-10	2.02E-09	2.35E-07	2.23E-06	2.17E-05	1.21E-04	4.70E-04	1.04E-03	1.16E-03	5.91E-05	1.41E-17
RA226	1.90E-11	7.47E-08	2.94E-05	1.15E-04	4.48E-04	1.90E-03	6.20E-03	1.49E-02	2.15E-02	1.93E-02	1.86E-02	1.83E-02
AC225	9.17E-12	2.28E-08	1.05E-06	1.23E-05	1.16E-04	1.13E-03	6.33E-03	2.45E-02	5.41E-02	6.04E-02	3.08E-03	7.37E-16
AC227	3.20E-12	1.21E-08	5.41E-07	7.85E-07	1.47E-06	3.68E-06	8.68E-06	1.68E-05	1.95E-05	1.95E-05	1.93E-05	1.77E-05
AC228	1.24E-16	5.30E-13	9.99E-12	1.68E-11	3.73E-11	1.16E-10	3.70E-10	1.30E-09	3.94E-09	1.31E-08	1.15E-07	4.31E-07
TH227	1.87E-10	7.47E-07	3.64E-05	5.29E-05	9.89E-05	2.48E-04	5.85E-04	1.13E-03	1.31E-03	1.31E-03	1.30E-03	1.19E-03
TH228	3.11E-07	6.00E-04	3.13E-07	4.75E-10	2.30E-10	7.19E-10	2.29E-09	8.01E-09	2.43E-08	8.06E-08	7.11E-07	2.66E-06
TH229	9.22E-12	2.03E-08	9.27E-07	1.08E-05	1.02E-04	9.97E-04	5.58E-03	2.16E-02	4.77E-02	5.32E-02	2.72E-03	6.49E-16
TH230	9.35E-08	2.06E-04	2.73E-04	4.31E-04	8.79E-04	2.38E-03	6.15E-03	1.48E-02	2.14E-02	1.93E-02	1.86E-02	1.83E-02
TH231	6.32E-06	1.06E-04	2.66E-05	2.67E-05	2.69E-05	2.76E-05	2.88E-05	3.03E-05	3.05E-05	3.05E-05	3.02E-05	2.77E-05
TH232	1.47E-14	3.24E-11	4.55E-11	7.68E-11	1.70E-10	5.31E-10	1.69E-09	5.92E-09	1.79E-08	5.95E-08	5.25E-07	1.97E-06
TH234	1.03E-04	2.95E-02	2.34E-04	2.34E-04	2.34E-04	2.34E-04	2.34E-04	2.34E-04	2.34E-04	2.34E-04	2.34E-04	2.30E-04
PA231	1.19E-08	2.63E-05	3.27E-05	4.75E-05	8.89E-05	2.23E-04	5.26E-04	1.02E-03	1.18E-03	1.18E-03	1.17E-03	1.07E-03
PA233	9.10E-06	4.68E-03	2.45E-03	2.88E-03	3.08E-03	3.08E-03	3.06E-03	3.00E-03	2.81E-03	2.24E-03	1.21E-04	2.67E-17
PA234M	1.49E-03	4.26E-01	3.38E-03	3.38E-03	3.38E-03	3.38E-03	3.38E-03	3.38E-03	3.38E-03	3.38E-03	3.38E-03	3.33E-03
PA234	2.67E-06	7.62E-04	5.98E-06	5.98E-06	5.98E-06	5.98E-06	5.98E-06	5.98E-06	5.98E-06	5.97E-06	5.97E-06	5.88E-06
U232	1.39E-09	3.24E-06	2.98E-07	3.54E-10	1.54E-18	0.	0.	0.	0.	0.	0.	0.
U233	1.25E-10	4.98E-07	6.32E-05	2.37E-04	7.91E-04	2.73E-03	7.93E-03	2.28E-02	4.54E-02	5.11E-02	2.61E-03	6.22E-16
U234	1.19E-05	2.61E-02	2.68E-02	2.70E-02	2.69E-02	2.68E-02	2.64E-02	2.50E-02	2.24E-02	1.94E-02	1.89E-02	1.86E-02
U235	4.26E-07	9.36E-04	9.37E-04	9.40E-04	9.47E-04	9.70E-04	1.01E-03	1.07E-03	1.07E-03	1.07E-03	1.06E-03	9.74E-04
U236	4.51E-07	9.92E-04	1.00E-03	1.03E-03	1.09E-03	1.24E-03	1.36E-03	1.38E-03	1.37E-03	1.34E-03	1.03E-03	7.60E-05
U237	2.66E-08	5.74E-05	4.94E-11	3.73E-12	3.16E-12	1.75E-12	3.28E-13	9.27E-16	4.83E-23	0.	0.	0.
U238	7.56E-06	1.66E-02	1.66E-02	1.66E-02	1.66E-02	1.66E-02	1.66E-02	1.66E-02	1.66E-02	1.66E-02	1.66E-02	1.64E-02

TABLE III-D-3 (Continued)

N REACTOR .947 ENRICHED PROPERTIES OF COLLECTED WASTE

POWER= 10.00MW, BURNUP= 1380.MWD, FLUX= 2.17E+13N/CM**2-SEC

NUCLIDE THERMAL POWER, WATTS
BASIS = 2200 TONS .947 ENR N REACTOR WASTE

	CHARGE	SEPARATION	3.0E+02YR	1.0E+03YR	3.0E+03YR	1.0E+04YR	3.0E+04YR	1.0E+05YR	3.0E+05YR	1.0E+06YR	1.0E+07YR	1.0E+08YR
NP237	2.03E-05	4.46E-02	5.33E-02	6.27E-02	6.70E-02	6.70E-02	6.66E-02	6.51E-02	6.10E-02	4.86E-02	2.64E-03	5.81E-16
NP239	8.83E-07	5.91E-03	5.73E-03	5.38E-03	4.46E-03	2.38E-03	3.89E-04	6.85E-07	1.05E-14	1.15E-15	7.86E-16	1.75E-17
PU238	2.35E-04	1.20E+00	3.49E-01	9.52E-03	9.85E-07	1.36E-20	0.	0.	0.	0.	0.	0.
PU239	2.02E-03	4.44E+00	4.40E+00	4.32E+00	4.09E+00	3.36E+00	1.92E+00	2.63E-01	8.98E-04	2.11E-12	1.81E-14	4.03E-16
PU240	7.15E-04	1.57E+00	1.53E+00	1.42E+00	1.19E+00	5.65E-01	7.28E-02	5.57E-05	6.94E-14	1.58E-17	1.71E-17	8.04E-18
PU241	6.62E-05	1.43E-01	1.23E-07	9.33E-09	7.84E-09	4.39E-09	8.20E-10	2.32E-12	1.21E-19	0.	0.	0.
PU242	9.92E-08	2.16E-04	2.37E-04	2.43E-04	2.43E-04	2.39E-04	2.31E-04	2.03E-04	1.41E-04	3.92E-05	2.79E-12	0.
AM241	5.58E-02	1.23E+02	7.85E+01	2.56E+01	1.04E+00	1.77E-05	6.60E-07	1.86E-09	1.03E-16	0.	0.	0.
AM242M	1.69E-06	3.71E-03	9.46E-04	3.89E-05	4.20E-09	5.88E-23	0.	0.	0.	0.	0.	0.
AM242	7.92E-06	1.75E-02	4.43E-03	1.82E-04	2.00E-08	2.76E-22	0.	0.	0.	0.	0.	0.
AM243	7.23E-05	1.59E-01	1.55E-01	1.45E-01	1.21E-01	6.42E-02	1.05E-02	1.85E-05	2.82E-13	3.11E-14	2.12E-14	4.74E-16
CM242	1.71E-01	2.24E+02	1.00E-01	4.13E-03	4.54E-07	6.26E-21	0.	0.	0.	0.	0.	0.
CM243	6.97E-06	1.52E-02	2.29E-05	5.99E-12	9.26E-31	0.	0.	0.	0.	0.	0.	0.
CM244	4.34E-04	9.41E-01	9.67E-06	2.22E-17	1.59E-22	5.26E-22	1.55E-21	4.82E-21	1.20E-20	2.31E-20	2.49E-20	1.17E-20
CM245	3.48E-09	7.66E-06	7.47E-06	7.04E-06	5.96E-06	3.31E-06	6.19E-07	1.75E-09	9.12E-17	0.	0.	0.
CM246	7.74E-11	1.70E-07	1.63E-07	1.47E-07	1.10E-07	3.91E-08	2.06E-09	6.96E-14	1.16E-26	0.	0.	0.
SUBTOT	2.32E-01	3.56E+02	8.52E+01	3.16E+01	6.54E+00	4.14E+00	2.22E+00	6.69E-01	6.48E-01	6.57E-01	2.19E-01	1.91E-01
TOTAL	2.32E-01	3.56E+02	8.52E+01	3.16E+01	6.54E+00	4.14E+00	2.22E+00	6.69E-01	6.48E-01	6.57E-01	2.19E-01	1.91E-01

APPENDIX III-E

AERODYNAMIC ENTRAINMENT OF WASTE SLURRIES SPILLED ON THE GROUND

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III-E AERODYNAMIC ENTRAINMENT OF WASTE SLURRIES SPILLED ON THE GROUND

The fraction of a slurry (a solid mixed in a liquid) spilled onto the ground that can be made airborne by the action of air passing over the surface depends upon many parameters. The influence of many of the parameters is variable and unquantified. Arriving at a precise fractional release value for a complex variable situation as an outdoor spill of a waste slurry on the surface is not feasible using the data currently available.

A limited amount of data is available on the fractional release of freshly dispersed powder (uranium dioxide with an Activity Median Aerodynamic Diameter of approximately 1 μm) and liquid (0.51 g uranium nitrate hexahydrate per cubic centimeter in dilute nitric acid).[1] The fractional airborne releases in a 24-hour period at various wind speeds are:

	2.5 mph	20 mph
Uranium dioxide	0.43 to 0.04	23 to 24.4
Uranium nitrate	0.012	0.039
Dried uranium nitrate (from solid residue after exposure of greater than 24 hours at stated air velocity)	0.007	1.1

The only comparable value is for the fractional release of uranium nitrate since it represents a wetted surface.

When a slurry is dispersed upon a porous surface, the liquid tends to penetrate into the surface and to separate from the solids. If the solids and surface are wetted by the liquid, solids dispersed upon the surface tend to behave as the soil surface. Since the value presented is for the liquid dispersed on soil, any entrainment of the soil coated with uranium nitrate would be measured. Entrainment of a wetted soil particle would tend to be less than dry particles of loose material in as much as the force required to overcome the surface tension is added to the force required to lift the dry particle. Other mechanisms such as being trapped in the interstice of larger soil particles or the tendency of flocculent particles to adhere to surface further reduce the aerodynamic entrainment of particles.

The evaporation of the liquid is the volatilization of the most volatile components of the liquid. Thus evaporation is akin to fractional distillation. In the case of spilled waste, the most volatile component is water and the rate of heat input under these conditions would produce little force to inject solid particles into the airstream. The liquid has a high salt content and tends to form a continuous layer of solid which reduces further evaporation. The fractional release from air-dried, solid residues is highly dependent upon the surface formed and forces applied to break up the surface.

Part of the forces applied are the turbulent eddies of air near the surface. Although the mean air velocity at the surface may be zero, fluctuations exist depending upon the air velocities and surface roughness. The air velocities in the wind tunnel experiments were measured one foot above a smooth surface of sandy soil. The stated windspeeds correspond to much higher windspeeds measured at higher levels.

Thus a fractional release of 10^{-3} during a 24-hour period following a liquid waste spill on soil appears to be a reasonable, though conservative, value to use for calculations.

III-E REFERENCES

1. J. Mishima and L. C. Schwendiman, Some Experimental Measurements of Airborne Uranium (Representing Plutonium) in Transportation Accidents, BNWL-1732, Battelle, Pacific Northwest Laboratories, Richland, WA, August 1973.

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APPENDIX III-F

TEN YEAR SUMMARY OF RANGE FIRES ON THE HANFORD SITE

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III-F TEN YEAR SUMMARY OF RANGE FIRES ON THE HANFORD SITE

A ten year summary (1964-1973) of fires (excluding building fires) is summarized graphically in a joint frequency distribution, Table III-F-1, with size of fire (acres) and date of fire (months) as the joint descriptors. The marginal totals are displayed as frequency distributions in Figure III-F-1.

TABLE III-F-1

SIZE AND DATE OF FIRES ON THE HANFORD RESERVATION 1964 THROUGH 1973

Size (Acres)		Month												
Average	Range	J	F	M	A	M	J	J	A	S	O	N	D	Σ
1/2	0-1				3	3	9	3	6	2		1		27
1-1/2	1-2				2	1	1							4
3	2-4					3	1	2						6
6	4-8		2	2	3	10	13	7	5	5	4			51
12	8-16					2	3	3	1					9
24	16-32					1	2	4	1	1				9
48	32-64							1	1	1	1			4
100	64-128						1		2		1			4
200	128-256													0
400	256-512					1	3							4
800	512-1024									1				1
1,500	1,000-2,000													0
3,000	2k-4k							1						1
6,000	4k-8k													0
12,000	8k-16k								1					1
24,000	16k-32k							1						1
	Σ	0	2	2	8	21	33	22	17	10	6	1	0	122

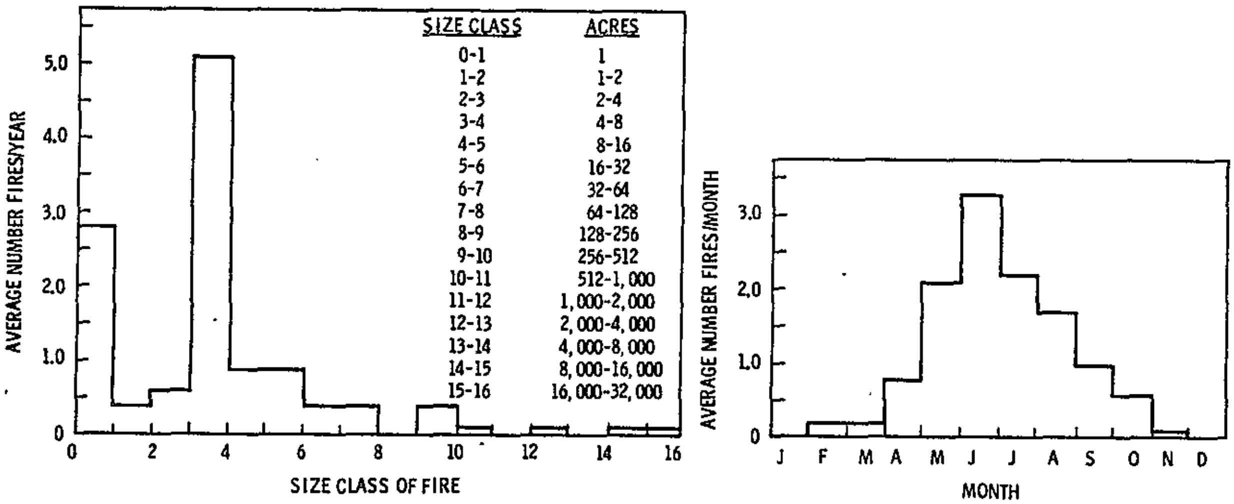

FIGURE III-F-1 RANGE FIRES ON HANFORD SITE

The average fire covered 310 acres and occurred at the end of June, but the few very large fires distort this average so greatly that other statistics are more appropriate. The mode is the most abundant observation in a sequence, and the median is that observation lying at the middle of the distribution - 50% above and below. The modal and median fires coincide, involving about 6 acres and occurring near the end of June. There are very many small fires, and very few large fires, occurring in time as a symmetric distribution around June. June is the most likely month for fire to occur because it contains the secondary maximum of precipitation (Volume 1, Section II), much in the form of thunderstorms. Usually, by June, cheatgrass and bunchgrasses have matured and dried to combustible conditions. However, this is not to imply that most fires are started by lightning; no data concerning the probable source for any of the fires exists except for the few very large fires, which were indeed from cloud-to-ground lightning strikes.

The impact of fires on the ecosystem was briefly discussed in Section II on characterization of the existing environment, because fires are a natural part of an arid landscape. Since most fires were kept small, their effect on the biota was very minimal. One growing season ordinarily sees much of the fire effect erased, both in plants and animals. This may not be true for the very large fires, because the sources for restocking are then well removed from the central area of the burn.

Fires are probably more common now than in earlier times because cheatgrass is now a "naturalized" member of many communities, and cheatgrass burns more readily than native grasses. The repercussions from this change in floristics may foretell the demise of sagebrush, for sagebrush is killed by fire and must restock the area by reseeding from outside. Since cheatgrass is most common in the sandy soils with unstable surfaces and little water, sagebrush has an uphill battle to restore its pre-burn density in the low elevation communities. Higher elevation communities, with bluebunch wheatgrass instead of cheatgrass, presents less of a problem for restocking by sagebrush, but still, restoration of a landscape probably would not occur in normal human lifetimes. The presence or absence of industrial activities probably will make little difference in this progression, except insofar as the spread of cheatgrass is encouraged by soil disturbance or seeding.

APPENDIX III-G

ENVIRONMENTAL SAMPLE COLLECTION, ANALYSIS, AND EVALUATION FOR 1974

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III-G ENVIRONMENTAL SAMPLE COLLECTION, ANALYSIS, AND EVALUATION FOR 1974

III-G.1 General

Environmental surveillance at Hanford has been conducted throughout the nearly three decades of Hanford operations. Extensive radiological data collected during this time provide a historical record* of environmental radioactivity due to Hanford operations, fallout from nuclear detonations in the atmosphere, and natural causes. Levels of radioactivity in air, Columbia River water, soil and sediments, milk, foods and biota have been studied extensively to estimate the effect of past once-through cooling production reactor operations. Nonradioactive pollutants in air and water have been measured during the past several years.

Monitoring activities during 1974 continued to measure the levels of pollutants, primarily radiological, in all local environmental media affording potential human exposure. Environmental air sampling stations were operated at several locations in the vicinity of Hanford for the purpose of measuring radioactive and nonradioactive pollutants. Routine measurements were made for chemical, biological, physical, and radiological parameters of Columbia River water. Levels of radioactivity in Columbia River fish, local wildlife, and locally grown foodstuffs were routinely measured. Oysters from Willapa Bay were analyzed for ^{65}Zn. External radiation levels were measured with environmental dosimeters, portable survey instruments, and aerial surveys.

In evaluating radiological data collected during 1974, the general philosophy was to compare radiation levels measured at locations potentially affected by Hanford operations with radiation levels measured at locations expected to reflect only radioactivity due to natural causes or nuclear testing fallout. Extensive data were collected for most environmental media to provide reliable estimates of the observed radioactivity which, in many cases, were near the detection limit of the analyses rather than unrealistic reliance on a few measurements.

Specific procedures were followed in evaluating the data. For each set of data where each individual analysis yielded a positive value, an annual average plus or minus two (±2) sample standard deviations (95% confidence interval) was calculated. Many sets of data contain individual analyses which were less than the detection limit. In such cases, a less-than annual average was calculated from the data assuming that each less-than value was equal to the detection limit. This method overestimates the annual average. Any identifiable contribution to the observed concentrations of radioactivity in air or water attributable to Hanford operations was compared to ERDAM-0524 regulations.[1] Observed concentrations of nonradioactive pollutants were compared to applicable standards promulgated by the State of Washington[2] or the Environmental Protection Agency.[3]

III-G.2 Air

Air sampling responsibilities for the Hanford environs are divided between Battelle-Northwest (BNW) and Hanford Environmental Health Foundation (HEHF). BNW is responsible for measuring the radiological parameters while HEHF is responsible for nonradiological parameters.

III-G.2.1 Radiological Evaluation

Radioactivity in the atmosphere was sampled by a network of 15 perimeter and 6 distant continuous air samplers during 1974 as shown in Figure III-G-1. Each air sampler maintains a flow of 2.5 m^3/hr through a particle filter (Hollingsworth & Vose Company, HV-70) and a 15-cm long, 5-cm diameter charcoal cartridge. The system is expected to collect nearly 100% of the radioactivity associated with airborne dust and both organic and elemental forms of radioiodine. The system does not collect noble gases or tritium. The filters were collected biweekly and analyzed for gross beta and alpha activity after waiting 7 days to allow the short-lived radon and thoron daughters to decay. The filters were composited into groups according to geographical location and analyzed monthly by gamma spectrometry and quarterly for ^{90}Sr and plutonium.

The results of gross beta, gross alpha, and ^{131}I analyses for perimeter and distant sampling locations are shown in Table III-G-1. The distant stations are sufficiently remote from Hanford operations that observed levels of radiation should be due to natural causes or fallout. During 1974, airborne beta concentrations followed the typical annual cycle with a midsummer maximum and a midwinter minimum. Figure III-G-2 illustrates these annual cycles for the years 1971 through 1974 in which the average monthly beta concentrations observed at eastern quadrant stations, which are located in the predominately downwind direction from Hanford operations, are compared with the concentrations observed at the distant stations. The gross beta concentration in the atmosphere usually begins to rise each spring following mixing and an increased rate of transfer

* A bibliography of past environmental surveillance reports is included at the end of this appendix.

of radioactivity (natural and fallout) from the lower stratosphere to the troposphere. The average beta concentration during 1974 observed at all perimeter stations was 1.7×10^{-13} μCi/ml, compared to 1.6×10^{-13} μCi/ml observed at all distant stations. The highest observed gross beta concentration during 1974, 5.6×10^{-13} μCi/ml, occurred at Benton City on June 25, 1974. During this time, daily samples were being collected to detect an expected increase in fallout radioactivity following a nuclear detonation in the atmosphere by the Peoples Republic of China on June 17, 1974. The observed increases coincided with the usual midsummer maximum (Figure III-G-2) and were only a small addition to the normal background due to natural radioactivity and fallout from previous nuclear detonations in the atmosphere.

Analyses for gross alpha concentrations in the offsite atmosphere are not expected to detect the minimal contributions from routine Hanford operations and, as such, were obtained at only a few locations in order to verify this as well as to detect any unusual increases due to natural or fallout radioactivity. The highest observed concentrations during 1974 occurred at Benton City (4.0×10^{-4} μCi/ml) [and Byers Landing (2.4×10^{-14} μCi/ml)] on June 26, 1974. These increases were apparently due to the nuclear detonation in the atmosphere by the Peoples Republic of China. The annual average concentration of gross alpha radioactivity was less than 2×10^{-15} μCi/ml at all locations.

Analyses for ^{131}I concentrations in the atmosphere were performed on a biweekly interval for 5 of the 15 perimeter sampling stations during 1974. Although charcoal cartridges were located at all perimeter and distant sampling stations, the majority were not analyzed but provided available samples if there had been any indication that iodine was present in the atmosphere. The charcoal for these stations was changed monthly. All ^{131}I analyses during 1974 were less than the detection limit of 0.07×10^{-12} μCi/ml, or less than 0.07% of the ERDAM-0524 standard of 1×10^{-10} for uncontrolled areas.[1]

Results of specific radionuclide analyses are shown in Table III-G-2. Beryllium-7 is a naturally occurring radionuclide formed by the interaction of cosmic rays with oxygen and nitrogen in the upper atmosphere. The other radionuclides are fission or activation products and result from either fallout, Hanford operations, or other nuclear facilities. An inspection of the data shows that all radionuclides, except for ^{103}Ru and ^{134}Cs, were observed in each composite group at approximately the same concentration. Cesium-134 (half-life = 2 years) was detected only once during the year during the time interval from the middle of June to the middle of July. Fallout from the Chinese test on June 17, 1974, was observed during this interval and was assumed to be the source of ^{134}Cs activity. Ruthenium-103 (half-life = 40 days) was also detected only once during the year during the time interval from the middle of May to the middle of June. The source was assumed to be fallout from past nuclear testing in the atmosphere. Neither ^{103}Ru nor ^{134}Cs were detected at any of the onsite air sampling stations.

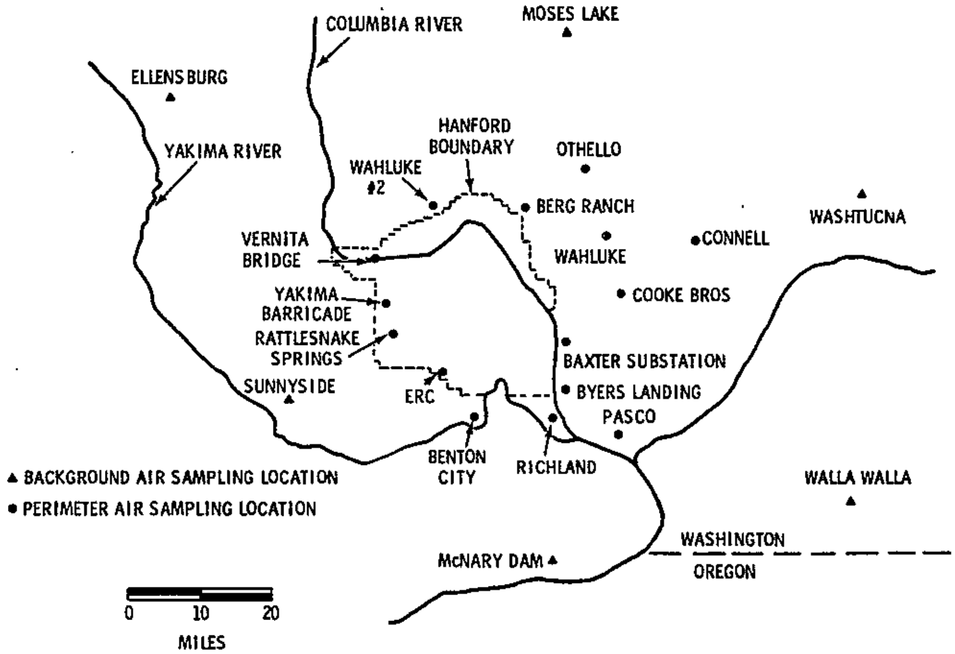

FIGURE III-G-1. HANFORD ENVIRONMENTAL AIR SAMPLING LOCATIONS DURING 1974

TABLE III-G-1

RADIOACTIVITY IN AIR - 1974

	Concentration (10^{-12} uCi/ml)[a]											
	Gross Beta				Gross Alpha[b]				Iodine-131			
Analytical Limit	0.02				0.0004				0.07			
Concentration Guide[c]	100.				0.03				100.			
Location	No. of Samples	Max.	Min.	Average	No. of Samples	Max.	Min.	Average	No. of Samples	Max.	Min.	Avg.
Perimeter Stations												
Baxter Substation	25	0.35	0.03	0.16±0.19					24	*	*	*
Benton City	37	0.56	0.03	0.21±0.26	37	0.04	*	<0.002	27	*	*	*
Berg Ranch	24	0.33	0.04	0.19±0.16	23	0.004	<0.001	<0.002				
Byers Landing	36	0.48	0.04	0.21±0.24	36	0.02	*	<0.002	27	*	*	*
Connell	24	0.33	0.03	0.14±0.18								
Cooke Bros.	27	0.31	0.03	0.13±0.16					26	*	*	*
ERC	27	0.36	0.04	0.17±0.20								
Othello	27	0.33	0.04	0.14±0.18								
Pasco	27	0.40	0.04	0.18±0.20								
Rattlesnake Springs	27	0.35	0.05	0.17±0.18								
Richland	35	0.97	0.04	0.21±0.36	37	0.004	*	<0.002	27	*	*	*
Vernita Bridge	27	0.33	0.03	0.17±0.18								
Wahluke	26	0.36	0.01	0.16±0.18								
Wahluke #2	25	0.34	0.02	0.16±0.16								
Yakima Barricade	25	0.36	0.03	0.17±0.20								
				0.17±0.05 (d)								
Distant Stations												
Ellensberg	16	0.28	0.04	0.15±0.13								
McNary Dam	26	0.43	0.06	0.16±0.18	25	0.005	*	<0.002				
Moses Lake	26	0.29	0.03	0.16±0.15								
Sunnyside	26	0.34	0.03	0.15±0.16								
Walla Walla	22	0.48	0.04	0.18±0.25	22	0.003	*	<0.001				
Washtucna	21	0.41	0.06	0.17±0.22								
				0.16±0.02 (d)								

No entry indicates no analysis.
* Less than detectable.
(a) 1 pCi/m^3 = 10^{-12} μCi/ml. Average ±2 sample standard deviations shown if all analyses had positive results. Otherwise, a less-than number is calculated from all results, including less-than values.
(b) Gross alpha activity does not include any significant contribution due to naturally occurring radon and short-lived daughters in the air. The filters are held 7 days before analysis to allow radioactive decay of these radionuclides.
(c) ERDAM-0524 standards only apply to concentrations of radioactivity in excess of that due to naturally occurring or fallout radioactivity.
(d) Average ±2 Sample Standard Deviations.

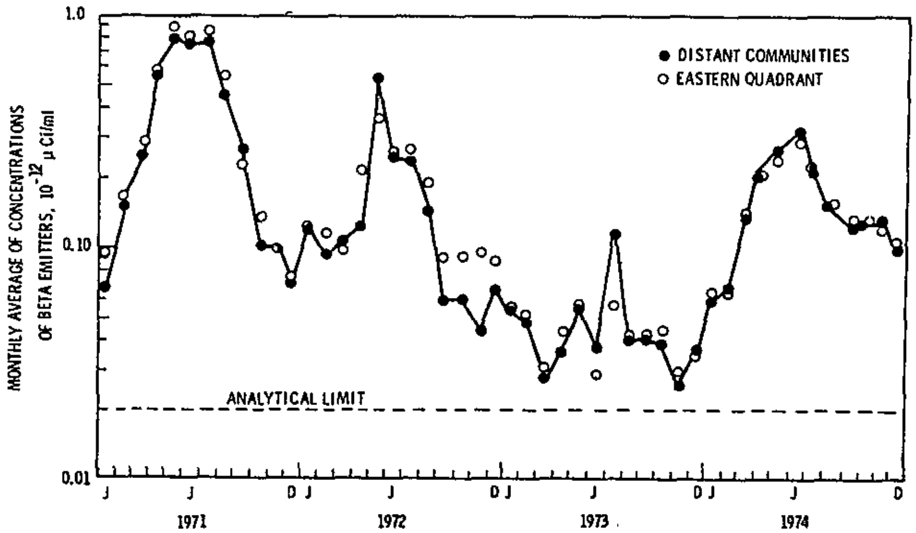

FIGURE III-G-2 MONTHLY AVERAGE GROSS BETA ACTIVITY IN THE ATMOSPHERE

TABLE III-G-2

CONCENTRATION OF SPECIFIC RADIONUCLIDES IN AIR - 1974

Location[b]	Radionuclide	Concentration (10^{-12} µCi/ml)[a] Maximum Observed	Minimum Observed	Annual Average	ERDAM-0524 Standard[c]
Inner Northeast Quadrant	Be-7	0.17	*	<0.06	40,000
	Mn-54	0.01	*	<0.007	1,000
	Zn-65	0.02	*	<0.001	2,000
	Sr-90	6×10^{-4}	2×10^{-4}	$(5\pm3)\times10^{-4}$	30
	ZrNb-95	0.06	0.01	0.03±0.03	3,000
	Ru-103	0.02	*	<0.002	3,000
	Ru-106	0.19	*	<0.09	200
	Cs-137	0.01	*	<0.003	500
	BaLa-140	0.33	*	<0.03	1,000
	CePr-144	0.18	*	<0.02	200
	Pu-total	5×10^{-5}	1×10^{-6}	$(2\pm4)\times10^{-5}$	0.06
Inner Southeast Quadrant	Be-7	0.31	*	<0.08	40,000
	Mn-54	0.01	*	<0.002	1,000
	Co-60	0.009	*	<0.002	300
	Zn-65	0.01	*	<0.001	2,000
	Sr-90	5×10^{-3}	4×10^{-4}	$(2\pm4)\times10^{-3}$	30
	ZrNb-95	0.05	0.007	0.03±0.03	3,000
	Ru-106	0.28	*	<0.12	200
	Cs-134	0.04	*	<0.004	400
	Cs-137	0.01	*	<0.002	500
	CePr-144	0.13	*	<0.06	200
	Pu-total	6×10^{-5}	1×10^{-5}	$(3\pm4)\times10^{-5}$	0.06
Outer Northeast Quadrant	Be-7	0.21	*	<0.009	40,000
	Mn-54	0.02	*	<0.005	1,000
	Co-60	0.004	*	<0.001	300
	Zn-65	0.007	*	<0.001	2,000
	Sr-90	3×10^{-3}	6×10^{-4}	$(1.3\pm2.4)\times10^{-3}$	30
	ZrNb-95	0.06	0.01	0.03±0.03	3,000
	Ru-106	0.23	*	<0.10	200
	Cs-137	0.009	*	<0.003	500
	BaLa-140	0.27	*	<0.02	1,000
	CePr-144	0.15	*	<0.05	200
	Pu-total	5×10^{-5}	1×10^{-5}	$(4\pm4)\times10^{-5}$	0.06
Outer Southeast Quadrant	Be-7	0.22	*	<0.07	40,000
	Mn-54	0.006	*	<0.002	1,000
	Co-60	0.003	*	<0.0004	300
	Sr-90	0.006	6×10^{-4}	$(3\pm5)\times10^{-3}$	30
	ZrNb-95	0.08	0.008	0.04±0.06	3,000
	Ru-106	0.29	*	<0.13	200
	Cs-137	0.01	*	<0.002	500
	CePr-144	0.28	*	<0.08	200
	Pu-total	5×10^{-5}	1×10^{-5}	$(7\pm3)\times10^{-5}$	0.06
Outer Western Quadrant	Be-7	0.22	*	<0.06	40,000
	Mn-54	0.01	*	<0.005	1,000
	Zn-65	0.008	*	<0.001	2,000
	Sr-90	0.007	6×10^{-4}	0.003±0.006	30
	ZrNb-95	0.06	0.005	0.03±0.04	3,000
	Ru-106	0.20	*	<0.1	200
	Cs-137	0.009	*	<0.003	500
	CePr-144	0.14	*	<0.04	200
	Pu-total	2×10^{-5}	*	$<1\times10^{-6}$	0.06

*Less than detection limit. Detection limit varies from sample to sample because of different airflow volumes, counting times, and radionuclide composition. Approximate tabled detection limits are: Be-7, 0.03; Mn-54, 0.002; Co-60, 0.003; Zn-65, 0.006; Sr-90, 0.002; ZrNb-95, 0.002; Ru-103, 0.003; Ru-106, 0.04; I-131, 0.12; Cs-134, 0.01; Cs-137, 0.003; BaLa-140, 0.15; CePr-144, 0.03; Pu-total, 0.000002.

(a) 1 pCi/m^3 = 10^{-12} µCi/ml
(b) Weekly air filters are composited into groups for monthly analysis of gamma spectroscopy or quarterly analyses for Sr-90 and Pu-total. Specific stations included in each quadrant are: Inner Northeast; Othello, Connell, Berg Ranch, Wahluke, and Cooke Bros. Inner Southeast; Richland and Pasco. Outer Northeast; Moses Lake and Washtucna. Outer Southeast; Walla Walla and McNary Dam. Outer Western; Sunnyside and Ellensburg.
(c) ERDAM-0524 Standards only apply to radionuclide concentrations in excess of that occurring naturally or due to fallout.

III-G.2.2 Nonradiological Evaluation

HEHF, under contract to ERDA, has the responsibility for monitoring the nonradiological quality of the atmosphere in the Hanford environs. Monitoring activities during 1974 included 24-hour sequential sampling for NO_2 and SO_2 at three locations across the Columbia River from Richland, North Richland, and Hanford 300 Area operations, as well as suspended particulate collection on the roof of the Federal Building in Richland. The three stations along the river were located in the southeasterly or downwind direction from Hanford operations. Table III-G-3 summarizes the NO_2 and dust data collected during 1974. The highest yearly average concentration of NO_2 measured was 0.006 ppm, or 12% of the ambient air standard of 0.05 ppm. Suspended particulates fluctuated widely due to occasional heavy dust storms. All SO_2 results were less than the detection limit of 0.005 ppm, or 25% of the ambient air standard of 0.02 ppm.

TABLE III-G-3

HANFORD ENVIRONS AIR QUALITY MEASUREMENTS - 1974

	NO_2 (ppm)					Suspended Particulates ($\mu g/m^3$)			
Annual Air Quality Standard	.05					60 + Background			
Location	No. of Samples	Daily Max.	Daily Min.	Annual Avg.	% of standard	No. of Samples	Daily Max.	Daily Min.	Annual Avg.
Richland (Fed. Bldg.)						125	572.[a]	8.	57.
Opposite Richland (Hobkirk Ranch)	78	0.022	0.001	0.006	12				
Opposite N. Richland (Gillum Ranch)	130	0.020	0.001	0.006	12				
Opposite 300 Area (Sullivan Ranch)	77	0.014	0.001	0.005	10				

No entry indicates no specific measurement was made.

(a) High value due to a local dust storm.

III-G.3 Water

III-G.3.1 Columbia River

The Columbia River from Grand Coulee Dam to the Washington-Oregon border, which includes the Hanford reach, has been designated as Class A (Excellent) by the Washington State Department of Ecology. This designation requires industrial uses of the river to be compatible with substantially all needs including sanitary water, recreation, and wildlife. Numerous routine samples are collected from the river to measure the effect of Hanford operations on the existing radiological, chemical, biological, and physical status of the river water. The Columbia River is a source of potable water for Hanford personnel and for the populace directly downstream of the Hanford site. Also, the river below Hanford is extensively used for recreation as well as a source of irrigation water for the Ringold and Riverview farming areas.

III-G-3.1.1 Radiological Evaluation

Samples of Columbia River water were obtained from Vernita Bridge, 100-B, Hanford powerline, 300 Area, and Richland. Since the shutdown of the last once-through cooling production reactor in January 1971, levels of radioactivity in river water have generally become undetectable with routine analytical methods. Table III-G-4 is a summary of the data obtained during 1974. The alpha measurements are an approximation of the naturally occurring uranium in the river. The observed values of ^{90}Sr and ^{239}Pu were attributed to fallout since concentrations measured upstream of Hanford operations did not differ from concentrations measured downstream. The majority of the observed tritium concentrations were due to fallout, although a small contribution ($\sim$10 pCi/l) would be present due to naturally occurring tritium. No other radionuclides were observed.

During 1974, a new method of sampling river water for radioactivity, refined by BNW's Radiological Chemistry staff,[4] was used, resulting in a much lower detection level for gamma-emitters. River water ($\sim$3 liters/hr) flows continuously through a nylon filter, a series of fiber glass filters, and a mixed bed ion exchange column. The nylon filter removes all particles greater than 5 microns and the series of fiber glass filters remove all particles greater than 0.3 microns.

TABLE III-G-4

ROUTINE ANALYSES OF COLUMBIA RIVER WATER - 1974

Concentration (10^{-9} $\mu Ci/ml$)[a]

		Upstream of Hanford[b]				Downstream of Hanford[c]				
Analysis	Analytical Limit	No. of Samples	Maximum Observed	Minimum Observed	Annual[d] Average	No. of Samples	Maximum Observed	Minimum Observed	Annual Average	ERDAM-0524[e] Standards
Alpha	0.2	12	0.9	*	<0.4	12	0.9	*	<0.4	30
H-3	380	12	710	*	<330	12	2000	*	<480	3,000,000
Sc-46	40	12	*	*	*	53	*	*	*	40,000
Cr-51	300	12	*	*	*	53	*	*	*	2,000,000
Co-60	20	12	*	*	*	53	*	*	*	30,000
Zn-65	40	12	*	*	*	53	*	*	*	100,000
Sr-90	0.04	12	2.5	*	<0.5	12	0.4	0.2	0.3±0.1	300
I-131	2	12	*	*	*	26	*	*	*	300
Cs-137	22	12	*	*	*	53	*	*	*	20,000
Pu-239	0.02	4	0.04	*	<0.02	4	0.04	*	<0.02	5,000

* Less than analytical limit.
(a) 10^{-9} $\mu Ci/ml$ = 1 pCi/l
(b) Upstream samples were obtained at Vernita Bridge (weekly grab samples) and at 100-B (cumulative sample).
(c) Downstream samples were obtained from the Richland sanitary water pumping dock (cumulative sample).
(d) Annual average ±2 sample standard deviations shown if all analyses were positive. Otherwise, a less-than number was calculated from the results, including less-than values.
(e) ERDAM-0524 standards only apply to concentrations in the environment in excess of naturally occurring or fallout radioactivity.

The filtered water flows through the resin to remove all soluble radionuclides directly with the exception of tritium. The filters and resin are changed biweekly and counted with a high sensitivity multi-dimensional (coincidence) gamma ray spectrometer to measure the different radionuclides.

The results for these samples, collected at the 300 Area, are shown in Table III-G-5 for 1974. Naturally occurring radionuclides observed were ^{40}K, ^{266}Ra, and ^{228}Th. The other radionuclides observed are artificially produced and must be due to either Hanford operations or worldwide fallout. All of these artificially produced radionuclides, except ^{152}Eu, were measurable in the atmosphere from fallout during 1974 as shown in Table III-G-2. Previous operation of once-through cooling production reactors released substantial quantities of ^{54}Mn, ^{60}Co, ^{65}Zn, and ^{152}Eu as well as other radionuclides to the Columbia River. These radionuclides became attached to sediments in the river and are still measurable in some locations.

A definite conclusion as to the primary source of the observed river concentrations of artificially produced radionuclides cannot be made. The method of sampling river water separates the collected radioactivity into either a particulate fraction (collected on filters) or a soluble fraction (adsorbed on resin). The majority of the artificially produced radionuclides were collected by filters, indicating that a likely source of these radionuclides was suspended sediments in river water. Although fallout definitely contributes to the measured concentrations of these radionuclides except for ^{152}Eu, past Hanford operations are assumed to contribute the greater amount. Europium-152 concentrations were due to past Hanford operations. All observed concentrations of radionuclides during 1974 attributable to Hanford operations were much less than 0.01% of ERDAM-0524 drinking water standards as shown in Table III-G-5.

The concentrations measured during 1974 of ^{54}Mn, ^{60}Co and ^{65}Zn were less than measured during 1973.[5] The reason(s) for the reduction in both the maximum observed value and the annual average is not known but expected to be related to the mixing and dilution of sediments labeled with these radionuclides with fresh sediments not so labeled. Also the river flow rate affects the amount of suspended sediments in the river causing variations in transport from year to year. The average river flow rate during 1973 was about 90,000 cfs (cubic feet per second), whereas during 1974 the average flow rate was about 150,000 cfs.

TABLE III-G-5

CONCENTRATIONS OF RADIONUCLIDES IN THE COLUMBIA RIVER[a]

10^{-9} μCi/ml

Radionuclide	Detection Limit	1974 No. of Samples	1974 Maximum Observed	1974 Minimum Observed	1974 Annual[b] Average	ERDAM-0524[c] Standard	Percent of[d] Standard
K-40	0.009	23	2.3	*	<1.0	-	-
Mn-54	0.014	23	<0.03	*	<0.01	100,000	$<1\times10^{-5}$
Co-60	0.0005	23	0.04	$<6\times10^{-5}$	0.02±0.02	30,000	$<7\times10^{-5}$
Zn-65	0.005	23	<0.04	$<1\times10^{-5}$	<0.01	100,000	$<1\times10^{-5}$
ZrNb-95	0.005	23	0.57	*	<0.12	60,000	-
Ru-106	0.005	23	0.20	0.02	0.12±0.09	10,000	-
Cs-137	0.005	23	<0.07	$<2\times10^{-4}$	<0.03	20,000	$<2\times10^{-4}$
Eu-152	0.02	23	<0.03	*	<0.02	60,000	$<4\times10^{-5}$
Ra-226	0.002	23	0.14	<0.01	<0.05	30	-
Th-228	0.0005	23	0.037	<0.005	<0.014	1,000	-

* Less than detection limit.

(a) Samples collected with a filter-ion exchange sampler developed by the radiological chemistry group at Battelle. Filters and resin counted directly after collection with a high sensitivity multi-dimensional gamma ray spectrometer.

(b) Annual average ±2 sample standard deviation shown in all analyses were positive. Otherwise, a less-than number was calculated from the results, including less-than values.

(c) ERDAM-0524 standards only apply to concentrations in excess of naturally occurring or fallout radioactivity.

(d) K-40, Ra-226, Th-228, occur naturally. ZrNb-95 and Ru-106 are due to fallout.

III-G.3.1.2 Nonradiological Evaluation

Measurements of water quality parameters other than radioactivity are routinely made on Columbia River water in order to:

- Detect any impact of the Hanford waste disposal practices on river water quality.
- Demonstrate continued compliance with Washington State Water Quality[2] Standards for the Columbia River and Public Health Service[6] recommendations for sources of drinking water.

Physical and chemical parameters measured during 1974 included pH, turbidity, dissolved oxygen, nitrate ion and temperature. Biological measurements included coliform organisms and BOD. Enterococci measurements were made to clarify the types of coliforms present. The parameters most likely to be affected by Hanford operations are temperature and nitrate ion. Figure III-G-3 shows the average monthly temperature measured at Priest Rapids Dam and at Richland during 1974. Some of the temperature difference is attributable to operations on the Hanford Reservation and some is due to natural causes.[7] The annual average temperature and 95% confidence interval for Priest Rapids Dam and Richland during 1974 were 11.2 ± 10.9 and 11.3 ± 11.3°C, respectively. Figure III-G-4 illustrates the daily variation of river temperature with season and flowrate during 1974.

Results of biological analyses of Columbia River water during 1974 are shown in Table III-G-6. The data indicate an increase of enterococci and BOD between Vernita bridge and Richland. These apparent increases are believed to be the result of drainage from farm activities and wildlife. The Hanford stretch of the river serves as a refuge for large population of water fowl.

Results of chemical analyses are shown in Table III-G-7. Nitrates, pH, turbidity, and dissolved oxygen were measured at both Vernita bridge and Richland. The measurements observed were similar at both locations and well within applicable standards adopted by the State of Washington for Class A rivers.[2] Average nitrate concentrations were less than 1% of the 45 ppm drinking water standard.[6] Average pH for 1974 was 8.1 at Vernita bridge and 7.8 at Richland, well within the 6.5 to 8.5 standard.

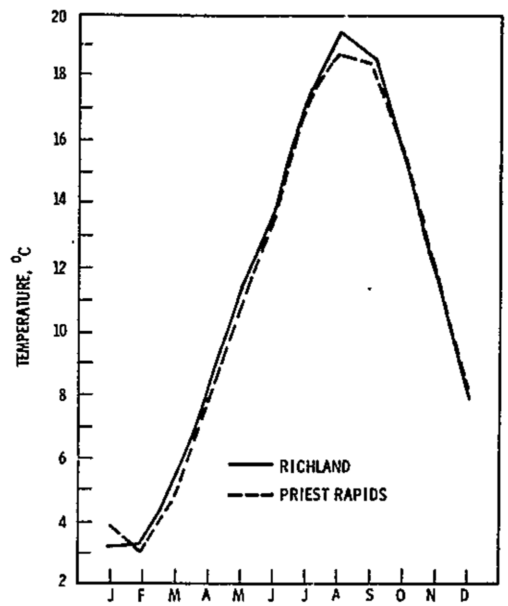

FIGURE III-G-3 COLUMBIA RIVER MONTHL'' TEMPERATURE AT RICHLAND AND PRIEST RAPIDS DAM FOR 1974

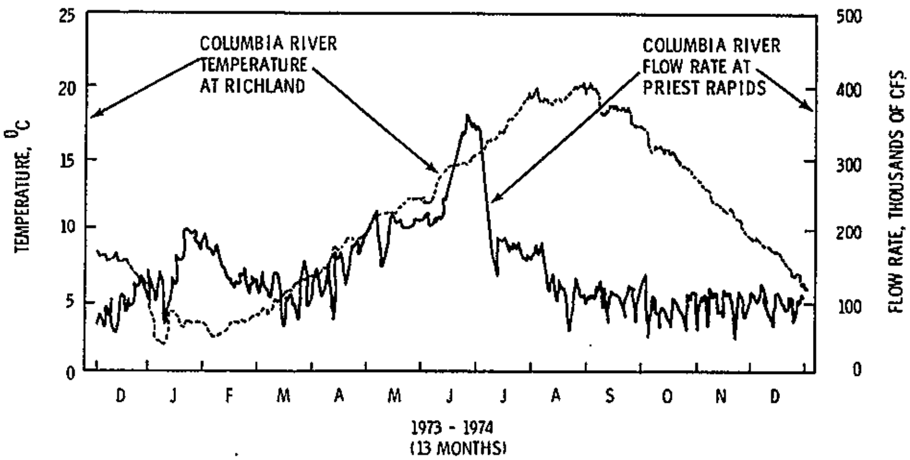

FIGURE III-G-4. COLUMBIA RIVER DAILY FLOW AND TEMPERATURE DURING 1974

TABLE III-G-6

COLUMBIA RIVER BIOLOGICAL ANALYSES - 1974

			Vernita				Richland			
Analysis	Unit	Standard	No. of Samples	Maximum Observed	Minimum Observed	Annual Average[a]	No. of Samples	Maximum Observed	Minimum Observed	Annual Average[a]
Coliform	No./100ml	240	12	120	9	43±72	12	150	4	54±74
Enterococci	No./100ml	--	12	64	3	29±40	12	194	4	61±98
BOD	mg/l	--	12	4.4	1.3	2.5±1.9	12	5.1	1.3	2.8±2.1

(a) Average ±2 sample standard deviations shown.

TABLE III-G-7

COLUMBIA RIVER CHEMICAL ANALYSES - 1974

			Vernita				Richland[a]			
Analysis	Units	Standard	No. of Samples	Maximum Observed	Minimum Observed	Annual Average	No. of Samples	Maximum Observed	Minimum Observed	Annual Average
NO_3	ppm	45	52	1.4	*	<0.4	52	1.2	*	<0.4
pH	--	6.5 to 8.5	51	8.7	7.7	8.1	242	8.6	7.0	7.8
Turbidity	JTU[b]	5+Bg	45	24	1	4.4	241	23.0	1.0	4.3
Dissolved O_2	mg/ℓ	8.0 min.	40	13.3	8.4	10.7	212	14.1	7.0	10.5

* Less than detection limit. Detection limit would be a tabled value of 0.1 for NO_3 analysis.

(a) pH, turbidity and dissolved O_2 samples obtained from 300 Area sanitary water pumping dock.

(b) Jackson turbidity units.

The turbidity standard is based on an increase of 5 JTU (Jackson turbidity units) above background. Since no observed differences were apparent between Vernita bridge and Richland the tabulated values were assumed to represent background. Average values for dissolved oxygen in the river were well above the minimum standard of 8 mg/l at Vernita bridge and Richland, during 1974, 10.7 mg/l and 10.5 mg/l, respectively.

III-G.3.2 Sanitary Water

The city of Richland is the first community below the Hanford Reservation that uses the Columbia River as a source of drinking water. BNW collects a cumulative (30 ml every 30 minutes) sanitary water sample at the Richland treatment plant for radiological analyses. HEHF routinely collects grab samples for analyses of bacteriological and chemical purity.

III-G.3.2.1 Radiological Evaluation

Cumulative sanitary water samples collected were analyzed on a weekly basis by gamma spectrometry and for gross beta and gross alpha analyses. The results of these analyses for 1974 are shown in Table III-G-8. The gross alpha measurement is an approximation of the naturally occurring uranium in the river. Strontium-90 was observed on several occasions and was due to fallout. No other radionuclides were observed. Specific analyses were not made for tritium in drinking water because the levels would be the same as observed in the river water (Table II-G-5) and the source is primarily fallout. Tritium is not removed by sanitary water treatment facilities.

III-G.3.2.2 Nonradiological Evaluation

Grab samples were collected from the Richland sanitary water system during 1974 for analyses of chemical and bacteriological purity. All bacteriological tests were negative and thus in compliance with the standard of no detectable coliform bacteria in potable water. Chemical analysis for nitrate was done on a weekly basis during 1974 (Table III-G-8). The annual average nitrate concentration was about 6% of the EPA drinking water standard of 45 ppm.[6]

III-G.3.3 Groundwater

An extensive ongoing groundwater monitoring program monitors any progress toward the Columbia River of low-level waste released to Hanford ground disposal sites. The data from this program are documented separately, the most recent report in this series being BNWL-1860.[8] A remote possibility exists that radioactive or process materials could penetrate to confined aquifers which generally underlie the Pasco Basin. Several farm wells on the east side of the Columbia River, which are believed to penetrate to these confined aquifers, are routinely sampled for tritium and nitrate ion. The data are not definitive, since contamination from the surface by nitrate from fertilizers and tritium from recent precipitation can also occur. Table III-G-9 shows data from these wells for 1974. All analytical results were less than the detection limits.

TABLE III-G-8

RADIOLOGICAL AND CHEMICAL ANALYSES OF DRINKING WATER - 1974[a]

Analysis	Analytical Limit	Units	Standards[b]	Richland No. of Samples	Richland Maximum Observed	Richland Minimum Observed	Richland Average
Radiological							
Alpha	0.3	pCi/l	30	52	0.9	*	<0.5
Beta	0.005	pCi/l	2,000,000	52	*	*	*
H-3	250.	pCi/l	3,000,000				N.A.
Sc-46	25.	pCi/l	40,000	52	*	*	*
Cr-51	350.	pCi/l	2,000,000	52	*	*	*
Co-60	20	pCi/l	30,000	52	*	*	*
Zn-65	40	pCi/l	100,000	52	*	*	*
Sr-90	0.08	pCi/l	300	10	0.6	*	<0.3
Cs-137	20.	pCi/l	20,000	52	*	*	*
Chemical							
NO_3	0.1	ppm	45	51	15	0.08	2.5±8.1

* Less than analytical limit
N.A. Not analyzed
(a) Average plus or minus two sample standard deviations shown if all analyses were positive. Otherwise, a less-than number was calculated from all results, including less-than numbers.
(b) Radiological standards derived from ERDAM-0524 apply only to concentrations in excess of natural or fallout activity. Nitrate standard was promulgated by the Environmental Protection Agency.

TABLE III-G-9

GROUNDWATER ANALYSES FROM WELLS IN THE VICINITY OF HANFORD - 1974

		^3H (10^{-9} Ci/ml)[a]			NO_3^- (ppm)		
Concentration Guide[b]		3,000,000			45		
Analytical Limit[c]		~950			0.5		
Location	Samples	Max.	Min.	Avg.	Max.	Min.	Avg.
Webber	2	<1200	<600	<900	*	*	*
Vail	2	<1000	<500	<750	*	*	*
W-15	2	<1200	<1000	<1100	*	*	*
White Bluffs Association	2	<1100	<900	<1000	*	*	*

* Less than the analytical limit
(a) 10^{-9} μCi/ml = 1 pCi/l.
(b) ERDAM-0524 Concentration Guides only apply to concentrations in excess of naturally occurring or fallout levels.
(c) Average analytical limit shown for tritium was calculated from the detection limit of each analysis.

III-G.4 Milk and Foodstuff

Foodstuffs, including milk, meat, chicken, eggs and leafy vegetables, were collected from local farms and commercial outlets. The samples were analyzed for gamma emitting radionuclides and ^{90}Sr. Tables III-G-10 through 12 show the results of these analyses. The data were used to evaluate the approximate dose received from eating these particular foods which comprise a significant fraction of the typical diet. Since the Riverview farming area is irrigated with Columbia River water after it has passed through the Hanford site, samples of each foodstuff were obtained from this area.

TABLE III-G-10

CONCENTRATIONS OF RADIONUCLIDES IN MILK - 1974

	Concentration (10^{-9} μCi/ml)[a] K-40	Sr-90	I-131
Analytical Limit	470	0.5	2.0
Concentration Guide[b]	-	200	100

Sample Results[c]

Location[d]	No. of Samples	K-40 Max.	K-40 Min.	K-40 Average	Sr-90 Max.	Sr-90 Min.	Sr-90 Average	I-131 Max.	I-131 Min.	I-131 Average
Riverview	26	1400	710	996±305	2.6	*	<1.7	3.0	*	<0.4
Wahluke	26	1300	860	1063±225	4.6	*	<2.0	*	*	*
Benton City #1	14	1100	730	937±285	4.1	*	<2.4	*	*	*
Benton City #3	12	1300	750	1035±317						
Benton City #4	12	1100	830	976±179	3.6	2.8	3.2±1.1	*	*	*
West Richland	5	1200	1000	1075±191				*	*	*
Commercial #1	11	1300	820	1043±268	5.5	*	<2.2	*	*	*
Commercial #2	13	1200	770	966±270	3.2	*	<1.9	*	*	*

No entry indicates no analysis
* Less than detectable
(a) 10^{-9} μCi/ml = 1 pCi/ℓ
(b) These concentration units are derived from Federal Radiation Council guidance on daily intakes, assuming one liter per day consumed. Potassium-40 is a naturally occurring radionuclide.
(c) The arithmetic mean ±2 sample standard deviations are tabled under the Average column if positive results were observed for each analyses. Otherwise, a less-than value is calculated from all the results, including less-than detectable values.
(d) Benton City #1 represents a composite of Benton City #3 and #4 before August 1, 1974. After August 1, the milk from each farm was analyzed separately. Milk from West Richland was obtainable only from May 2 through June 27, 1974. The commercial sources obtain milk from two different watersheds: commercial #1 west of the Cascade mountain range, commercial #2 east.

TABLE III-G-11

CONCENTRATIONS OF RADIONUCLIDES IN MEAT, CHICKEN, AND EGGS - 1974

Concentration (10^{-6} μCi/gm) wet weight[a]

Sample Location	No. of Samples	K-40 Max.	K-40 Min.	K-40 Average	Sr-90 Max.	Sr-90 Min.	Sr-90 Average	Cs-137 Max.	Cs-137 Min.	Cs-137 Average
Meat										
Commercial	11	2.6	1.8	2.1±0.5	0.001	*	<0.001	0.04	*	<0.01
Riverview	1			1.7			*			*
Chicken										
Commercial	2	1.6	1.5	1.6±0.1	*	*	*	*	*	*
Riverview	4	2.0	1.0	1.8±1.0	*	*	*	*	*	*
Eggs										
Commercial	2	1.0	1.0	1.0±0.0	*	*	*	*	*	*
Riverview	11	1.1	0.7	0.9±0.2	0.004	*	<0.003[b]	*	*	*

* Less than detectable. Approximate tabled detection limits would be: K-40, 0.4; Sr-90, 0.001; Cs-137, 0.03.
(a) 10^{-6} μCi/gm = 1 pCi/gm. The arithmetic mean plus or minus two sample standard deviations are tabled under the average column if positive results were observed for each analysis. Otherwise, a less-than value is calculated from all of the results, including less-than detectable values.
(b) Sr-90 analysis done on only 4 samples.

TABLE III-G-12

CONCENTRATIONS OF RADIONUCLIDES IN LEAFY VEGETABLES - SPINACH, LETTUCE (LEAF), TURNIP GREENS, MUSTARD GREENS - 1974

		Concentration (10^{-6} μCi/gm) wet weight[a]								
		K-40			Mn-54			Co-60		
Sample Location	No. of Samples	Max.	Min.	Average[b]	Max.	Min.	Average	Max.	Min.	Average
Riverview	5	3.6	1.7	2.4±1.4	*	*	*	*	*	*
Benton City	1			7.9			*	*	*	*
Commercial	6	5.2	1.4	2.1±1.8	0.36	*	<0.07	0.05	*	<0.01

		Sr-90[c]			ZrNb-95			Ru-106		
Sample Location	No. of Samples	Max.	Min.	Average	Max.	Min.	Average	Max.	Min.	Average
Riverview	5	0.016	0.011	0.014±0.005	0.11	*	<0.04	0.96	*	<0.25
Benton City	1			N.A.			0.04	*	*	*
Commercial	6	0.010	0.009	0.010±0.001	0.77	*	<0.18	*	*	*

No entry indicates no analysis.
* Less than detectable. Tabled detection limits would be approximately: K-40, 0.8; Mn-54, 0.04; Co-60, 0.05; Sr-90, 0.002; ZrNb-95, 0.03; Ru-106, 0.7.
N.A. Not analyzed
(a) 10^{-6} μCi/gm = 1 pCi/gm.
(b) Average plus or minus two sample standard deviations.
(c) Analysis for Sr-90 was not run on each sample. Number of samples analyzed was 3 for Riverview and 2 for commercial

Potassium-40, a naturally occurring radionuclide, contributed the majority of the radioactivity measured in all samples. Strontium-90 was measured in several samples and the observed levels result from fallout, not Hanford operations. The other nuclides were detected only occasionally, and in several cases at levels only slightly above the detection limit of the analyses. To obtain absolute measurements with such low levels of radioactivity is extremely difficult; several of the tabled values may represent nothing more than the statistical variability of background.

Iodine-131 was detected on June 24, 1974 in one milk sample from the Riverview farming area. This activity was most likely due to fallout from the June 17, 1974 nuclear detonation in the atmosphere by the Peoples Republic of China. Fallout debris from this test was measured in the atmosphere during June 24 and 25. Subsequent analyses failed to detect any ^{131}I in milk samples from the Riverview area or any other area.

In summary, the majority of the radioactivity measured in foodstuffs during 1974 was the result of naturally occurring ^{40}K and ^{90}Sr due to fallout. Other radionuclides detected occasionally were believed to be from worldwide fallout.

III-G.5 Wildlife

Samples of wildlife, including gamebirds, fish, and deer, were routinely collected from the Hanford environs and analyzed for levels of radioactivity. Table III-G-13 lists the results obtained during 1974. Fish, usually whitefish, were collected monthly from the Columbia River and the composite analyzed. Gamebirds were collected along the Columbia River, primarily during hunting season. The deer were "road-kills." The radionuclide present in the greatest quantity was ^{40}K, a naturally occurring radionuclide. Cobalt-60, ^{65}Zn, ^{90}Sr, and ^{137}Cs were observed in several samples of fish at levels very near the detection limit of the analyses. Cobalt-60 was observed in one duck out of the 33 collected; the observed quantity (0.12) was very near the detection limit of the analysis (0.08). Cobalt-60 and ^{65}Zn were observed in only one sample (different ones) out of the 14 geese analyzed and, again, at levels very near the detection limit of the analyses.

The origin of the ^{60}Co and ^{65}Zn activity is assumed to be due to previous operation of the once-through cooling production reactors, as discussed under the Columbia River Section. Strontium-90 and ^{137}Cs activity were due to fallout.

TABLE III-G-13

CONCENTRATIONS OF RADIONUCLIDES IN MUSCLE TISSUE OF SELECTED WILDLIFE OBTAINED FROM THE HANFORD ENVIRONS - 1974

		Concentration (10^{-6} µCi/gm) wet weight[a,b]															
	No. of	K-40			Co-60			Zn-65			Sr-90			Cs-137			
Wildlife	Samples	Max.	Min.	Average	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	
Fish	12	3.9	2.1	3.1±1.1	0.27	*	<0.08	0.16	*	<0.06	0.007	*	<0.002	0.09	*	<0.06	
Ducks	33	4.0	*	<2.3	0.12	*	<0.09	*	*	*	0.007	*	<0.006	*	*	*	
Geese	14	3.4	2.2	2.7±0.8	0.17	*	<0.09	0.18	*	<0.16	0.009	*	<0.005	0.21	*	<0.1	
Pheasants	15	3.7	*	<2.9	*	*	*	*	*	*	*	*	*	*	*	*	
Deer	3	2.3	2.2	2.2±0.1	*	*	*	*	*	*	*	*	*	1.8	*	<1.0	

* Less than detectable. Tabled detection limits would be approximately: K-40, 1.0; Co-60, 0.06; Zn-65, 0.11; Sr-90, 0.002; Cs-137, 0.06.

(a) 10^{-6} µCi/gm = 1 pCi/gm

(b) Average plus or minus two sample standard deviations reported if all analyses were positive. Otherwise, a less-than value was calculated from all results, including less-than values.

Willapa Bay oysters were collected in 1974 and analyzed for ^{65}Zn activity. Zinc-65 has a 245-day halflife and the observed decline of activity in oysters, as shown in Figure III-G-5, closely approximates the radioactive decay rate. The radioactive decay rate will result in a loss of approximately 64% of the activity every year since early 1971, when the last once-through water-cooled reactor was shut down.

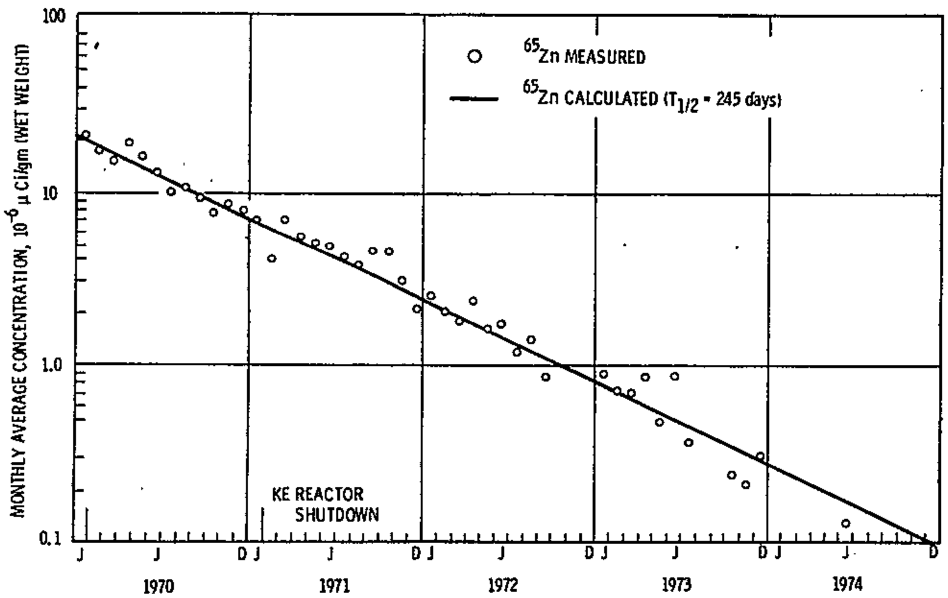

FIGURE III-G-5 ZINC-65 CONCENTRATION IN WILLAPA BAY OYSTERS DURING 1970 THROUGH 1974

III-G.6 Soil and Vegetation

Surface soil and perennial vegetation samples were collected from 17 different locations during the autumn of 1974 for the purpose of measuring the levels of radioactivity due to fallout and natural causes as well as to assess any potential buildup of radioactivity from Hanford operations. These locations are shown in Figure III-G-6 and the results listed in Tables III-G-14 and III-G-15. Each soil sample represents the composite of five "plugs" of soil from an approximate 10 m^2 area. Each plug was approximately 2.5 centimeters (1 inch) in depth and 10 centimeters (4 inches) in diameter. The vegetation samples were collected in the immediate vicinity of each soil sampling location and consisted of perennial vegetation, primarily the new growth from rabbit-brush plants. Both sets of samples were analyzed for gamma emitting radionuclides using a lithium drifted germanium detector, for plutonium nuclides using alpha spectroscopy, and for ^{90}Sr and uranium by specific analysis.

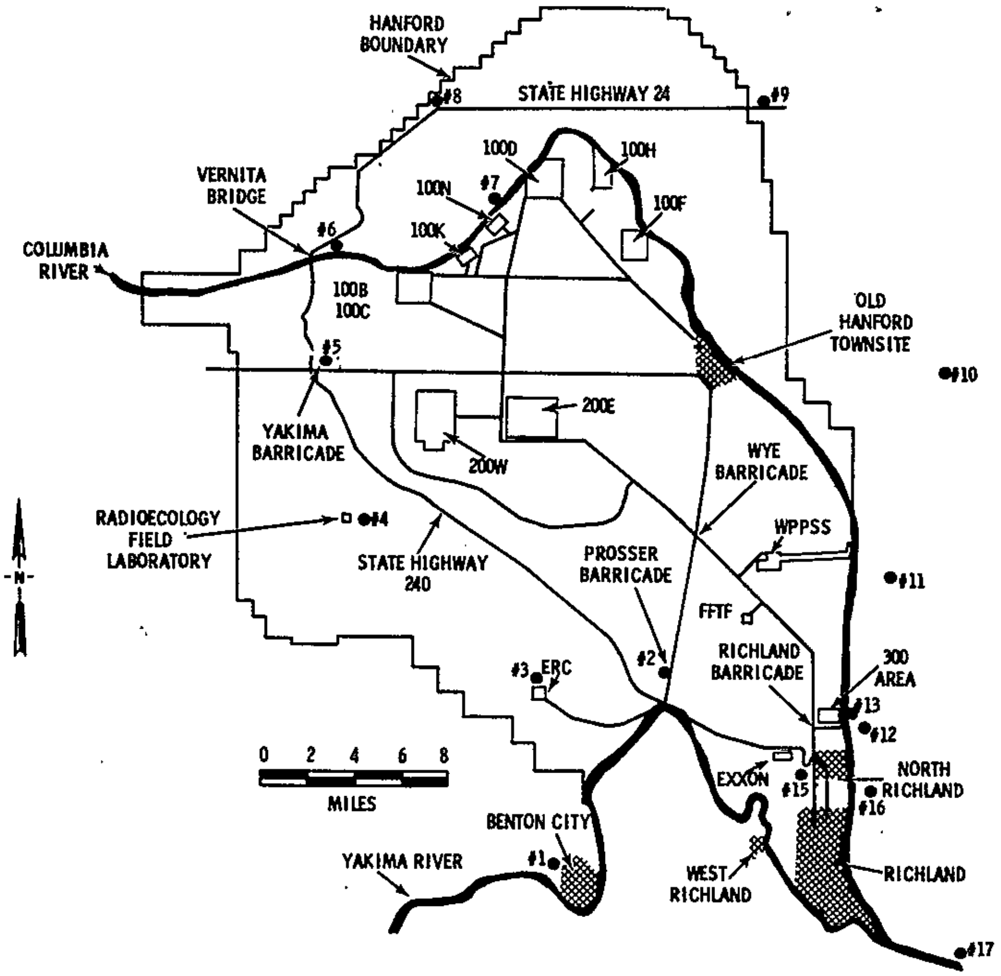

FIGURE III-G-6 SOIL AND VEGETATION SAMPLING LOCATIONS DURING 1974

The radionuclides observed in soil samples from all locations were ^{40}K, ^{90}Sr, ^{137}Cs, ^{224}Ra, ^{226}Ra, and uranium. All of these radionuclides occur naturally except for ^{90}Sr and ^{137}Cs. Strontium-90 and ^{137}Cs, as well as the other artificially produced radionuclides shown in Table III-G-14 and III-G-15, are produced by fission and must be due to either Hanford operations, other nuclear facilities, or to fallout of radioactive debris from the atmosphere due to past nuclear device testing. Hanford operations would be expected to contribute much more so to radionuclide concentrations measured at predominately downwind sampling locations (Baxter Substation, Byers Landing, 300 Area south gate, etc.) than to sampling locations lying in an improbable wind direction from Hanford facilities (Vernita bridge, Wahluke #2, etc.). No distinct pattern is apparent. Hence, any contributions from Hanford operations to radioactivity measured at the different sampling locations were indistinguishable from the variability in concentrations due to fallout.

Partly because of other information (Section III-G.7.4), the ^{60}Co concentration for the sample collected on Island #340 is expected to be due to past Hanford operations. As discussed in Section III-G.3, certain radionuclides, notably ^{60}Co, still remained in the river sediments due to past operation of once-through cooling production reactors. The flooding of Island #340 during past periods of high river flow with deposition on the island of sediments suspended in the river is the probable reason for the observed concentration of ^{60}Co.

III-G.7 External Radiation Measurement

External radiation levels in the Hanford environs were measured during 1974 by several methods. Thermoluminescent dosimeters (TLDs) were deployed at 13 perimeter and 6 distant locations to measure the ambient radiation dose received from natural and fallout radioactivity as well as to

TABLE III-G-14

CONCENTRATIONS OF RADIONUCLIDES IN SURFACE SOIL - 1974
Units of 10^{-6} μCi/g (wet weight)

Sample Location	Map Location	Naturally Occurring Radionuclides				Artificially Produced Radionuclides											
		^{40}K	^{224}Ra	^{226}Ra	U-total	^{58}Co	^{60}Co	^{65}Zn	^{90}Sr	^{95}Zr	^{95}Nb	$^{106}RuRh$	^{134}Cs	^{137}Cs	^{144}Ce	^{238}Pu	$^{239-240}Pu$
Analytical Limit		0.50	0.04	0.11	0.034	0.03	0.03	0.07	0.002	0.10	0.10	0.40	0.03	0.03	0.10	0.003	0.001
Benton City	1	13	1.4	0.83	0.29	*	*	0.24	0.78	*	*	0.74	*	1.7	0.31	*	0.04
Prosser Barricade	2	14	0.92	0.48	0.13	*	0.04	0.23	0.48	0.20	0.11	0.75	0.06	0.91	*	*	0.01
ERC	3	13	0.95	0.73	0.70	0.02	*	0.21	0.02	0.24	*	0.40	0.05	0.11	0.13	*	0.002
Radioecology Field Lab.	4	12	0.71	0.46	0.32	*	*	0.08	0.34	0.13	*	0.50	0.06	0.96	0.32	*	0.02
Yakima Barricade	5	14	0.76	0.73	0.10	*	*	*	0.01	0.12	*	0.47	*	0.11	0.62	*	0.003
Vernita Bridge	6	18	0.81	0.46	0.13	*	*	*	0.02	0.16	*	0.68	*	0.10	0.33	*	0.004
Wahluke Slope	7	14	0.66	0.50	0.24	*	*	*	0.02	0.10	*	0.63	0.04	0.15	0.19	*	0.004
Wahluke #2	8	13	5.9	0.91	0.11	*	*	0.08	0.02	0.15	*	0.85	*	0.23	*	*	0.01
Berg Ranch	9	12	1.4	0.72	0.07	*	*	0.15	0.05	0.29	*	0.43	0.12	0.45	0.11	*	0.007
Cooke Bros.	10	12	0.64	0.55	0.39	*	*	0.17	0.06	*	*	0.47	*	0.07	0.44	*	0.003
Baxter Substation	11	16	0.74	0.52	0.36	0.04	*	0.23	0.06	0.25	*	0.48	0.05	0.26	0.34	0.01	0.004
Byers Landing	12	12	0.97	0.46	0.39	*	*	0.35	0.25	0.12	*	0.54	0.06	0.69	0.20	*	0.006
Byers Pumphouse	13	12	0.88	0.48	0.61	*	0.07	0.20	0.38	0.20	0.15	0.70	*	1.8	0.44	*	0.02
300 Area South Gate	14	14	0.54	0.56	0.66	0.03	0.05	0.29	0.12	*	*	0.59	*	1.5	0.25	*	0.02
North Richland	15	14	0.92	0.72	0.26	0.03	*	0.18	0.26	*	*	0.98	*	0.48	0.16	*	0.007
Island #340	16	12	0.76	0.78	0.45	*	2.4	0.19	0.08	0.33	0.17	0.62	0.04	1.9	0.17	*	0.04
Riverview	17	13	0.56	0.31	0.42	*	0.04	0.27	0.04	0.10	*	0.40	0.06	0.06	*	*	0.002
Maximum		18	5.9	0.91	0.66	0.04	2.4	0.35	0.78	0.33	0.17	0.98	0.12	1.9	0.62	0.01	0.04
Minimum		12	0.54	0.46	0.07	*	*	*	0.01	*	*	0.40	*	0.06	*	*	0.002
Avr. ±2 Sample Deviations[a]		13±3	1.2±2.5	0.60±0.3	0.33±0.4	<0.01	<0.16	<0.17	<0.18±0.4	<0.15	<0.07	0.60±0.3	<0.04	0.68±1	<0.24	<0.001	0.01±0.02

* Indicates result was less than the analytical limit shown.

(a) Average and two sample standard deviations shown if radionuclide detected at all locations. Otherwise, a less-than number is calculated from the other results, including less-than values.

TABLE III-G-15

CONCENTRATIONS OF RADIONUCLIDES IN VEGETATION - 1974

Units of 10^{-6} μCi/g (dry weight)

Sample Location	Map Location	Naturally Occurring Radionuclides				Artificially Produced Radionuclides											
		^{40}K	^{224}Ra	^{226}Ra	U-total	^{58}Co	^{60}Co	^{65}Zn	^{90}Sr	$^{95}ZrNb$	$^{106}RuRh$	^{131}I	^{137}Cs	$^{140}BaLa$	$^{144}CePr$	^{238}Pu	$^{239-240}Pu$
Analytical Limit		1.0	0.04	0.11	0.034	0.06	0.07	0.13	0.002	0.05	1.0	1.1	0.06	2.1	0.62	0.003	0.001
Benton City	1	10	*	*	0.19	*	*	0.63	0.06	0.78	*	*	0.10	7.9	*	*	0.002
Prosser Barricade	2	9	*	*	*	*	*	0.80	0.04	0.28	*	*	0.18	14	*	*	*
ERC	3	13	*	*	0.12	*	*	0.98	0.02	0.14	*	*	0.13	14	*	0.003	0.001
Radioecology Lab.	4	9.0	*	*	*	*	*	0.52	0.05	0.28	*	*	0.16	11	0.58	*	0.003
Yakima Barricade	5	8.5	*	*	*	0.67	*	0.36	0.05	1.1	*	*	0.09	7.7	*	*	0.002
Vernita Bridge	6	11	*	*	*	*	*	0.77	0.06	1.3	*	*	0.24	14	1.2	*	0.001
Wahluke Slope	7	9.6	*	*	0.05	*	*	0.76	0.03	0.37	*	*	0.12	15	0.98	*	*
Wahluke #2	8	11	*	*	0.08	*	*	0.80	0.13	0.30	*	*	0.15	17	*	*	0.001
Berg Ranch	9	11.	*	*	0.16	*	*	0.84	0.06	0.22	*	*	0.12	15	*	*	0.003
Cooke Bros.	10	20	*	*	0.23	*	*	1.8	0.04	0.13	*	*	0.12	29	2.3	*	*
Baxter Substation	11	18	*	*	0.34	*	*	1.3	0.14	0.14	*	*	0.10	20	*	*	0.002
Byers Landing	12	10	*	*	7.2	*	*	0.79	0.02	0.30	*	*	0.19	11	0.52	*	0.002
Byers Pumphouse	13	11	*	*	*	*	*	1.0	0.02	4.0	*	*	0.46	15	*	*	0.001
300 Area South Gate	14	11	*	*	0.21	*	*	0.63	0.17	0.52	*	*	0.46	10	2.2	*	0.005
North Richland	15	8.4	*	*	0.09	*	*	0.43	0.07	0.26	*	*	0.13	8.8	0.51	*	0.004
Island #340	16	4.7	*	*	0.32	*	*	*	0.12	0.31	1.3	*	0.15	3.6	1.0	0.002	0.02
Riverview	17	10	*	*	0.22	*	*	0.45	0.06	0.32	*	*	0.14	9.7	0.41	*	0.002
Maximum		20	*	*	7.2	0.67	*	1.8	0.17	4.0	1.3	*	0.46	29	2.3	0.003	0.02
Minimum		4.7	*	*	*	*	*	*	0.02	0.14	*	*	0.09	3.6	*	*	*
Avr. ±2 Sample Deviations[a]		11±7	*	*	<0.55	*	*	<0.76	0.07±0.09	0.63±1.9	*	*	0.18±0.2	13±11	<0.43	<0.0005	<0.003

* Indicates result was less than the analytical limit shown.

a. Average and two sample standard deviations shown if radionuclide detected at all locations. Otherwise, a less-than number is calculated from the other results, including less-than values.

detect any contribution from Hanford operations. TLDs were submerged in the Columbia River at 4 locations. State highways through the site, control plots, and Columbia River shoreline were routinely surveyed with portable instruments to detect any trend in ambient radiation levels. An aerial survey, using sensitive monitoring equipment, was flown over the Columbia River by E.G.&G. of Las Vegas.

III-G.7.1 Ambient Radiation Dose

TLDs were used to measure the external background dose at several perimeter and distant communities. Table III-G-16 shows the results of these measurements. The dosimeter employed consisted of 3 chips of CaF_2:Dy (Harshaw TLD-200) encased in an opaque plastic capsule lined with 0.010 inches of tantalum and 0.002 inches of lead to flatten the lower energy response.[9] The dosimeters were mounted approximately one meter above ground level and changed either biweekly or monthly.

The external dose measured at any location is affected by several parameters, including the height of the dosimeter, elevation, and the amount of natural and fallout radioactivity in the

TABLE III-G-16

AMBIENT RADIATION DOSE - JANUARY-DECEMBER 1974[(a)]

Location	No. of Measurements[(b)]	Dose (mrad/yr)[(c)] Maximum	Minimum	Average
Perimeter Community Dose				
Eltopia	11	69	55	62±9
Pasco	14	80	66	73±9
Richland	27	80	55	66±14
Vernita	15	116	69	84±22
Benton City	13	66	55	62±9
Othello	14	73	55	62±9
Connell	14	73	55	66±11
Berg Ranch	14	95	69	80±15
Wahluke Wm	14	84	66	77±12
Cooke Bros.	14	77	55	69±13
Ringold	11	69	55	62±17
Baxter Sub.	13	77	44	66±18
Byers Landing	14	88	69	77±11
Average ± 2 sample standard deviations				70±15
Distant Community Dose				
Ellensberg	10	66	44	51±13
Walla Walla	13	80	62	73±10
Sunnyside	14	69	55	66±9
McNary	14	80	62	73±11
Moses Lake	14	73	58	66±7
Washtucna	14	84	58	69±13
Average ± 2 sample standard deviations				66±16

(a) Total background dose from external irradiation would include an additional dose from the neutron component of cosmic radiation. This is estimated to be equivalent to 6 mrem/year at the elevation of the Hanford region (EPA publication ORP/SID 72-1).
(b) Dosimeters are generally deployed on a two-week or four-week interval. This practice results in approximately 26 or 13 separate measurements at each location. There is some variability because of scheduling and year-to-year overlap.
(c) Monthly or biweekly measurements converted to equivalent annual dose. Average ±2 sample standard deviations calculated for each location.

underlying soil and in the atmosphere. The variability in measured dose from the different locations was expected primarily because of the spatial dependence of natural radioactivity in soil. Contributions from Hanford operations were indiscernible from the variability in background dose measured at the different communities.

From the information in Table III-G-16, the external background dose received by the population in the Hanford environs can be estimated. The average measured dose and 95% confidence interval was about 70 ± 15 mrem/year (1 mrem equals 1 mrad in this case). To this number, an additional 6 mrem/year must be added to account for the neutron component of cosmic radiation.[10] Thus an estimate of 76 ± 15 mrem/year from external radiation would be realistic. An estimate of the total (external plus internal) background dose must include the approximate 25 mrem/year received from radioactivity, primarily ^{40}K, in our bodies.[16] Therefore, the average total background dose received in the Hanford environs is approximately 100 ± 15 mrem/year.

III-G.7.2 Columbia River Immersion Dose

TLDs were submerged in the Columbia River at four locations: Coyote Rapids (above 100-K Area), below 100-N, Hanford powerline, and the Richland pumphouse. The TLDs were collected monthly and the results (shown in Table III-G-17) are similar to 1973.[18] The information was used to evaluate the dose rate received while swimming in the river. At Richland, an immersed swimmer would receive approximately 0.004 mrad/hr, compared to approximately 0.008 mrad/hr received on land (Table III-G-16).

TABLE III-G-17

COLUMBIA RIVER IMMERSION DOSE RATE - 1974

Location	No. of Measurements	(Radiation Dose (mrad/hr)[(a)] Maximum Observed	Minimum Observed	Annual[(b)] Average
Coyote Rapids	11	0.007	0.004	0.005±0.002
Below 100-N	13	0.008	0.004	0.005±0.002
Hanford Powerline	10	0.01	0.003	0.007±0.004
Richland Pumphouse	13	0.005	0.004	0.004±0.001

(a) Monthly measurements in mrad were converted to equivalent hourly dose.
(b) Average ±2 sample standard deviations calculated for each location.

III-G.7.3 Portable Instrument Surveys

Roads and land surfaces in the vicinity of Hanford were periodically surveyed to detect possible radionuclide deposition resulting from Hanford operations and related activities. Public Highways 24 and 240, which traverse the Hanford Reservation, were surveyed quarterly with a bioplastic scintillation detector attached to the bumper of a truck and positioned about 0.6 meters (2 ft) above the edge of the road surface.[11] During 1974, no radioactivity other than background was detected.

Eleven small areas, called control plots, measuring 3m x 3m (10 ft x 10 ft) were surveyed monthly or semi-monthly with a Geiger-Muller survey meter for deposited radioactive material. No surface radioactivity of Hanford origin was detected on these control plots during 1974.

Each month, the shoreline of the Columbia River was surveyed with a low-level GM counter (Nuclear Enterprises Model 2601) at selected locations to detect any change in ambient radiation levels from previous measurements. The data obtained during 1974 for three of these locations, Vernita, Richland and Sacajawea, are summarized in Table III-G-18. No statistical difference is apparent between the results for the three locations given the wide variability in observed values.

TABLE III-G-18

COLUMBIA RIVER SHORELINE EXPOSURE RATE - 1974

Shoreline Location	No. of Measurements	Exposure (mR/hr) Maximum Observed	Minimum Observed	Annual[(a)] Average
Vernita	10	0.013	0.005	0.010±0.006
Richland	12	0.014	0.009	0.011±0.003
Sacajawea	25	0.015	0.008	0.011±0.003

(a) Average ±2 sample standard deviations for each location.

III-G.7.4 Aerial Surveys

Between March 26 and April 28, 1974, a detailed aerial survey of Columbia River shoreline and islands was conducted by E.G.&G. of Las Vegas.[12] The survey covered an area from approximately 4 kilometers above Vernita Bridge to approximately 10 kilometers below the intersection of the Snake River with the Columbia River. An additional 2 kilometers downstream from McNary Dam was also surveyed. The survey was conducted at an altitude of 45 meters using a Navy helicopter. Flight minimum of three lines spaced 60 meters apart were flown along each bank, starting at the shoreline and moving inland. Similar patterns were flown over the islands. The counting system employed consisted of two pods, each containing twenty 12.5 cm diameter by 5 cm thick NaI(Th) detectors, mounted externally on the helicopter. The signals from the detectors were fed into three units: a gross count scaler, a set of five adjustable window single channel analyzers, and a 300 channel multichannel analyzer.

The highest radiation levels observed offsite during the aerial survey occurred on the islands between the old Hanford townsite and the 300 Area. A maximum reading of 0.014 mR/hr due to ^{60}Co was obtained. No ^{137}Cs activity above background levels was observed. The average external exposure rate in the Hanford environs is approximately 0.010 mR/hr. Subsequent to the aerial survey, soil samples were taken on the islands. The samples were analyzed for all gamma emitting radionuclides. The results are shown in Table III-G-19. A comparison of the average concentrations of the different radionuclides observed on the islands with the concentrations observed in surface soil (Table III-G-14) reveals that the island samples were higher for all radionuclides, including naturally occurring radionuclides. Previous measurements[5] of Columbia River sediments have shown similar quantities of the observed radionuclides except $^{106}RuRh$. Ruthenium-rhodium-106 is routinely observed in the atmosphere (Table III-G-2) and in the Columbia River (Table III-G-5). An inspection of the biweekly data available in the BNWL-1910 ADD shows that the $^{106}RuRh$ levels measured in the Columbia River parallel the radioactivity diurnal cycle observed for fallout radionuclides in the atmosphere (Figure III-G-2). The observed readings in island soil samples (including Island #340 sample) are expected to be primarily due to past Hanford operations for all radionuclides except $^{106}RuRh$ and naturally occurring radionuclides.

Although not contributing significantly to the measured exposure rates, seven discrete radioactive particles were detected during follow-up ground survey, buried one to four inches deep in sandy areas showing elevated exposure rates. The only measurable radionuclide was ^{60}Co. The particles are believed to have resulted from past Hanford reactor operations. Even if disturbed, these particles would afford no significant exposure risk in view of their scarcity, size and insolubility.

III-G.8 Radiological Impact of Hanford Operations

Potential environmental exposure pathways from Hanford operations to the population are shown pictorially in Figure III-G-7. Many of these same pathways are responsible for transporting naturally occurring and fallout radioactivity from the environment to man. The evaluation of monitoring data from several environmental media discussed in the previous sections attempted to determine the contribution to ambient radiation levels due to Hanford operations from the contributions due to fallout and natural radioactivity. The contribution from Hanford operations during 1974 to the radiation levels measured in all environmental media (atmosphere, water, foodstuffs, wildlife, soil, and vegetation) were indistinguishable from pre-existing radiation levels. Some of the radioactivity that was measured in occasional samples of wildlife, suspended

TABLE III-G-19

GAMMA EMITTING RADIONUCLIDES IN ISLAND SOIL SAMPLES - 1974

Units of 10^{-6} μCi/gm (dry weight)

Sample Location[(a)]	Naturally Occurring Radionuclides K-40	Ra-224	Ra-226	Artificially Produced Radionuclides Mn-54	Cr-51	Co-60	Zn-65	RuRh-106	Cs-137	Eu-152	Eu-154
Island #348	16.	0.7	0.7	0.3	0.5	10.	3.0	2.9	3.6	6.7	1.5
Island #345	18.	3.5	1.2	0.5	*	11.	0.7	3.4	2.6	5.1	1.5
Island #344	16.	2.1	0.8	0.3	0.2	6.	1.3	1.7	2.7	6.7	1.0
Island #342	18.	6.1	1.0	0.2	*	3.	0.4	1.1	1.8	2.6	0.6
Island #341	16.	4.1	1.0	0.4	*	6.	1.4	2.0	1.9	2.9	0.6
Island #340	19.	4.4	0.7	0.3	*	7.	2.4	2.3	2.4	4.3	2.1
Island #333	18.	4.3	0.6	0.3	*	1.	0.6	1.5	1.1	1.1	0.3
Island #332	19.	5.0	0.6	0.2	0.1	4.	1.1	1.6	1.4	1.7	0.7
Maximum	19.	6.1	1.2	0.5	0.5	11.	3.0	3.4	3.6	6.7	2.1
Minimum	16.	0.7	0.6	0.2	*	1	0.4	1.1	1.1	1.1	0.3
Average ± 2 sample standard deviations[(b)]	18±3	3.8±3.4	0.8±0.4	0.3±0.2	<0.3	6±7	1.4±1.8	2.1±1.5	2.2±1.6	3.9±4.3	1.0±1.2

*Less than detectable

(a) River mile of island used as identification.

(b) Average plus or minus two sample standard deviations shown if radionuclide detected at all locations. Otherwise, a less-than number is shown.

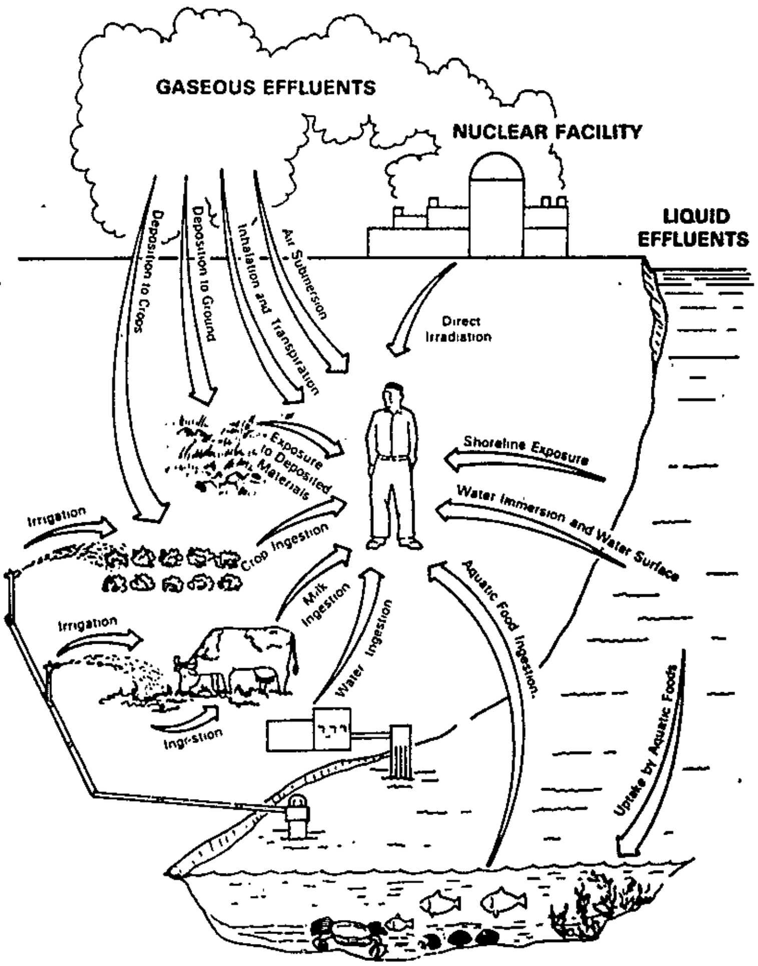

FIGURE III-G-7 EXPOSURE PATHWAYS TO MAN[13] sediment in river water, soil samples from Columbia River islands, and oysters from Willapa Bay was due to past once-through cooling production reactor operations. The last of these reactors, KE, was deactivated during January 1971. The radioactivity in the river sediments and biota due to this cause is gradually becoming undetectable through dilution and radioactive decay. Table III-G-20 lists the radionuclide composition of effluent reported by all Hanford contractors during 1974.

TABLE III-G-20

RADIONUCLIDE COMPOSITION OF EFFLUENT - 1974(a)

Radio-nuclide	Half life	Effluent (Curies) Liquid to River	Gaseous 100 Areas	Gaseous 200 Areas	Gaseous 300 Areas
H-3(HTO)	12.3 yr	190.	4.2		
Na-24	15 hr	1.0			
P-32	14.3 d	0.004			
Ar-41	1.8 hr		50,000		
Sc-46	84 d	0.02			
Cr-51	28 d	0.22			
Mn-54	303 d	0.5			
Mn-56	2.6 hr	5.0			
Co-58	71 d	0.02			
Fe-59	46 d	0.18			
Co-60	5.3 yr	1.2			$<5x10^{-5}$(b)
Zn-65	245 d	0.2			
As-76	26.4 hr	0.03			
Sr-90	28 yr	0.3	$5x10^{-6}$	<0.2(c)	$<4x10^{-4}$(c)
Nb-95	35 d	0.1			
Zr-95	66 d	0.11			
Mo-99	67 hr	<0.6			
Tc-99	$2.1x10^{5}$ yr	<0.1			
Ru-103	40 d	0.12			
Ru-106	368 d	0.5			
Sb-122	2.8 d	<0.01			
Sb-124	60 d	<0.07			
Sb-125	2.7 yr	0.02			
I-131	8 d	2.33	0.5		$<3x10^{-3}$
I-132	2.3 hr		0.1		
I-133	20.3 hr		2.2		
Xe-133	5.3 d	0.003	0.15		
Cs-134	2.0 yr	0.02			
I-135	6.7 hr		3.1		
Xe-135	9.1 hr		1.8		
Cs-137	30.0 yr	0.12			
BaLa-140	12.8 d	0.8			
Ce-141	32.5 d	0.05			
Ce-144	284 d	0.103			
W-187	23.9 hr	<0.01			
Np-239	2.3 d	0.02			
Am-241	458 yr				$<3x10^{-7}$
Pu-Alpha(d)	24,390 yr		$<4x10^{-7}$	$<2x10^{-3}$	$<4x10^{-5}$
U-Alpha(d)	$4.5x10^{9}$ yr				$<4.3x10^{-4}$
Particulates(e)	---		0.23		

(a) Table includes all reported releases.
(b) Actually reported as mixed activation products. Cobalt-60 assumed for simplification and was used in dose calculations.
(c) Actually reported as mixed fission products. Strontium-90 assumed for simplification and was used in dose calculations. For 300 Area, $2x10^{-4}$ curies of Sr-90 was reported. The additional, $<2x10^{-4}$, was reported as mixed fission products.
(d) Gross alpha counts for different facilities interpreted as either reflecting Pu-239 or uranium activity depending on the nature of the operations inside the facilities.
(e) Gross activity collected on particle filter. Subsequent analyses have shown the majority of the particulate activity to be Mo-99. This radionuclide was used in the dose calculations.

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